Historical Context and Preliminary Resource Evaluation of the Elizabeth Mine, South Strafford, Orange County, Vermont

Supplement to *Statement of Limits, National Register Eligibility, and Potential Resources in the Proposed APE, Elizabeth Mine, South Strafford, Vermont*, *Hartgen Archaeological Associates, Inc., October 2000.*

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for
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And The

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Executive Summary

The Public Archaeology Laboratory, Inc. (PAL) was contracted by Arthur D. Little, Inc., on behalf of the Environmental Protection Agency (EPA), to conduct archival research and to assemble supplemental information in support of the *Statement of Limits, National Register Eligibility, and Potential Resources in the Proposed APE, Elizabeth Mine, South Strafford, Vermont*, prepared by Hartgen Archaeological Associates, Inc. (October 2000). The supplemental information presented in this document was generated to respond to report comments made by the Vermont State Historic Preservation Office (VTSHPO), the community and other official commentors.

Elizabeth Mine is a designated National Priorities List (Superfund) site, and as such, the EPA is coordinating the hazardous material cleanup of the site to protect human health and the environment. The EPA determined that the Elizabeth Mine Site is eligible for inclusion in the National Register of Historic Places, based on the documentation provided in the Hartgen report (letter from E. Hathaway to E. Wadhams, dated January 10, 2001). The VTSHPO concurred with the EPA's finding of National Register eligibility and concluded that the site is eligible as the Elizabeth Mine Historic District, although the district's formal boundaries have not yet been determined (letter from E. Wadhams to E. Hathaway, dated March 9, 2001). While the site or district boundaries have not been determined, the EPA recognizes that any proposed cleanup action at the site has the potential to adversely affect some portion of the historic property.

This supplemental report provides historic context information at the national, regional, state and local levels for the Elizabeth, Ely, and Pike Hill mine sites in Orange County, Vermont. This report identifies all of the known discrete areas of historic mining-related activity at the Elizabeth Mine, and discusses their historic, landscape and archaeological values. The known and potential historic and archaeological resources at each of the sites are discussed in terms of their chronological history, including their periods of significance, landscape evolution, and function and technology. This report also includes preliminary evaluation of the physical integrity, archaeological research value and interpretive potential of areas of the Elizabeth Mine. The contextual and descriptive information and statements regarding overall site significance and interpretive potential will assist the EPA and VT SHPO in determining the effects of proposed cleanup activities on known resources and archaeologically sensitive areas at the Elizabeth Mine site.

This report partially fulfills EPA's compliance with Section 106 of the National Historic Preservation Act and its' implementing regulations, 36 CFR Part 800. It identifies and evaluates the historic properties that may be affected by EPA's actions. Additional areas of research are identified and recommendations are made for future consideration of the historic properties. When the final alternatives for EPA action are selected and all interested parties have been consulted, a Memorandum of Agreement will be executed.

Site Description

Elizabeth Mine, established in the early nineteenth century and operated until the mid-twentieth century, is located in the village of South Strafford, in the town of Strafford in Orange County, Vermont. It lies approximately one-half mile south of the West Branch of the Ompompanoosuc River, a tributary of the Connecticut River, in the rugged uplands of east-central Vermont. This part of Orange County hosted mining activity in the approximately 20-mile long Copper Belt, and by the late nineteenth century was the location of several other mining operations, including the Ely Mine in Vershire and Pike Hill Mines (Eureka and Union) situated in the town of Corinth. Today, the Elizabeth Mine site contains major mining landscape features, numerous standing structures, visible machinery and other related materials, and the aboveground and buried remains of structures and features related to several periods of mining operations at the site. The surviving historic landscape at the Elizabeth Mine is focused on the core area of 1809 to 1958 mining activity at South Strafford. This area includes Tailings Piles (TP) 1, 2 and 3, and an intact cluster of mine buildings. Additionally, there are two known discontiguous resources associated with the mine, the Sharon Power Station in Sharon and Pompanoosuc Station in Norwich.

Historic Values of Areas at the Elizabeth Mine

The historic resources at the Elizabeth Mine can be viewed in terms of their visual landscape value and their potential archaeological value. Mining landscapes are the physical result of choices made based on the nature of the geology, location, time period, available technology, market conditions, and other factors that changed and evolved over time. Mining landscapes are complex places with overlapping layers of historic activity and landscape evidence. The historic resources at a mine site are not just limited to standing structures; they encompass the entire landscape and the full range of excavations, waste materials, transportation routes, and other aspects of mining operations. Due to industrial and natural processes, many of the resources at historic mining sites are completely or partially buried and are considered archaeological resources with the potential to reveal important information.

The most immediate and visible historic resource at the Elizabeth Mine are the major landscape elements left over from the nineteenth-century copperas production and mid-twentieth-century copper production in the form of waste rock, roast beds, heap leach piles, and flotation mill tailings. Tailings Piles 1, 2 and 3 all possess high historic value as mining landscapes. From a historical perspective, these masses of material are the most obvious and most powerful evidence of the human activity at the mine site and are expressive of important economic and technological changes. Additionally, these landscape elements possess other values. The size, mass, shape, geometry, texture and color of the tailings, and the lack of vegetation at the mine site are all extremely unusual for a New England industrial landscape. The productivity of the mine and range of processes and products resulted in the most extensive and colorful of the Orange

County copper mine landscapes. The mining landscape at TP 1 includes the only intact cluster of historic hard rock metal mining buildings in New England, which include a flotation mill that is a unique example of its class in the Eastern U.S. These areas have high potential to interpret copperas and copper ore production technology as well as additional ecological and environmental subjects.

In addition to their visual landscape value, the tailings piles also have value for their archaeological potential. TP 1 and TP 2 cover the remains of a variety of historic ore beneficiation and smelting sites dating from about 1900 to 1930. Although the bulk of these sites are deeply buried and are not likely to be impacted by cleanup activities, the 1900 Tyson mill and blacksmith shop appear to have been located where TP 1 and TP 2 meet east of the World War II-era mine buildings and their remains could be shallow enough to be potentially impacted by cleanup activities along the west slope of TP 1.

Tailings Pile 3 has been identified as the location of nineteenth-century copperas production and therefore possesses high historic research value for its potential to contain archaeological information that could help interpret this poorly understood early industrial process. Reports generated by the cleanup activity have included the north open cut, and all the open land north and east of it in TP 3. This area was, however, the site of an additional phase of industrial activity not associated with the copperas works. The area north of the north open cut was actually the scene of mining for the Tyson's 1882 to 1890 smelting activities on Sargent Brook at the west foot of Copperas Hill. The area within TP 3 north of the north open cut is the eastern component of this later smelting area and is significant as it is a key component of the only historic area at the Elizabeth Mine that clearly shows the entire process of mining, roasting, smelting and slag disposal in an uninterrupted, linear manner. The waste ore lying at the surface in this area, which has been tentatively identified as the main source of metals contamination at TP 3, is likely waste ore left over from the cobbing activities associated with Tyson's copper ore mining from Shaft No. 1 and Shaft No. 2. This area has the potential to contain archaeological remains of this activity and has high research and interpretive value as the source of ore for a series of related features that together demonstrate a complete industrial process.

Statement of Significance

The Elizabeth Mine is eligible for listing in the National Register of Historic Places at the local, state and national levels for its contributions to the history of South Strafford, the State of Vermont and the United States. These areas of significance include commerce, economics, engineering, industry, and invention. The Elizabeth Mine was the site of a major U.S. copperas manufacturing plant that dominated production of this important industrial chemical during the mid-nineteenth century. It was the scene of several important firsts in American copper metallurgy, including successful mineside smelting, large-scale smelting of sulfide ores, and smelting with hot blast and anthracite and successful use of chromite refractories. After its revival during World War II it briefly became one of the 20 most productive copper mines in the U.S. and was the largest and most productive copper mine in New England.

President James Monroe visited the Elizabeth Mine in 1817 as part of a goodwill tour of areas industries affected by changing trade regulations. The early nineteenth-century copperas production and copper smelting activities were superintended by Isaac Tyson, Jr., a Baltimore, Maryland-based chemical and mining figure who was recently inducted into the American Institute of Mining, Metallurgical and Petroleum Engineers (AIME) Mining Hall of Fame. During the early twentieth century, extensive mine redevelopment and smelting experiments were undertaken by August Heckscher, general manager of the New Jersey Zinc Company (one of the major U.S. zinc producers) and currently nominated to the AIME Mining Hall of Fame. The mine was the subject of examination and reports by several noted nineteenth- and twentieth-century mining engineers.

The Elizabeth Mine constitutes one of the largest and most intact historic mining sites in New England and includes the only intact cluster of historic hard-rock metal mining buildings in the region. Its landscape includes resources that represent the transition from small-scale nineteenth-century mining to large-scale twentieth-century mining, and both copperas and copper production. It includes a diverse range of features from mining, milling and smelting activity. The Elizabeth Mine includes areas devegetated by mining activity, roads and other transportation routes, pits, shafts, tailings and waste rock piles, building foundations and standing remains, and archaeological elements now visible or that may be present based on documentary sources including historic maps and photographs. The surviving World War II flotation mill is a particularly rare resource for the Eastern U.S. Deposits of waste material including TP 1 and TP 2 are valuable historic resources as they are major landscape features that are expressive of metallurgical technology.

The Elizabeth Mine site has the potential to yield archaeological evidence of industrial and technological activities spanning almost 160 years. The copperas production area has already been identified as an area of particular archaeological sensitivity for its potential to contain information about this poorly understood early industrial process. Other areas have the potential to contain archaeological evidence for various phases of copper ore extraction, transportation, beneficiation and smelting from later phases of activity. Some of these sites are intact and others have been buried under wastes associated with later mining activity. The presence, location and nature of those very waste materials are also considered archaeological resources at this site. The domestic and processing sites and buildings also have the potential to reveal information about the lifeways of nineteenth and twentieth century miners.

Ely Mine

The Ely Mine was discovered after the deposit at South Strafford. The Ely Mine was active between the mid-1850s and about 1905, and its main contribution to U.S. copper mining occurred during the 1870s and 1880s. The Ely Mine included a major 1867 smelting works that expanded to become a massive non-ferrous metallurgical plant, more than 700 ft long with 24 smelting furnaces. During the second half of the nineteenth century, the Ely Mine outstripped copper production at the Elizabeth Mine. The Ely was among the top ten producing U.S. copper mines between 1866 and 1881. It was the third largest-producing U.S. copper mine in 1873 and 1875, and ranked fourth through ninth in the rest of that decade. The mine's overall production stands somewhere between 30 and 40 million lbs. of copper. The Ely Mine was significant as a mining boomtown in Vermont, included a substantial workers' village and influenced the local economy. It was the scene of labor unrest that resulted in the "Ely War." It was the site of several early-twentieth-century experiments testing new technologies aimed at efficient extraction of copper from low-grade ores and mine wastes. The Ely Mine was the only copper mine in Vermont where all technological aspects of copper production, from mining of raw ore to smelting of refined pig copper, were successfully integrated on a large scale.

The Ely Mine landscape includes roughly 350 acres of land characterized by barren ground, and includes slag heaps, waste rock piles, the foundations of a massive smelter building, a stone smoke flue, fieldstone retaining walls, roast beds, mine openings and scattered foundations, and the remains of a dam and stone quarry. Expected resources include archaeological remains of an extensive village that included more than 50 houses, a large general store, three churches, a school, post office, sawmill, gristmill, blacksmith shop, stables and private businesses. The scale of operations indicated in the documentary record suggests that many additional industrial archaeological resources can be expected. Post-mining activity includes removal of some of the waste rock for milling at the Elizabeth Mine and removal of a portion of the slag heap. The extensive remains of the unique smelter plant and smoke flue, 900 ft roast beds, and other features present the opportunity to explore one of the largest nineteenth-century non-ferrous metallurgical plants in New England, archaeological documentation of which would be an important contribution to the understanding of this site. The Ely Mine site has the potential to interpret copper production in a clear way as operations were temporally confined using similar technology and the geography dictated a confined, straight-line flow of materials that can be readily understood. The site is easy to access by public road, however, the property is currently privately owned.

Pike Hill Mines

The Pike Hill orebody in Corinth was discovered after the deposits in South Strafford and Vershire. Pike Hill was the scene of intermittent copper mining from 1846 to 1919. The Pike Hill mines went by several names but the largest were the Union and Eureka mines. Although the Pike Hill mines operated sporadically and were overshadowed by the Ely Mine and the Elizabeth Mine, they contributed an estimated 1/17th of the copper produced in the Orange County Copper Belt. There was no smelting at Pike Hill; ore mined there was taken to Ely to be refined. One significant technological achievement was magnetic separation of the pyrrhotite from the milled ore at the Union Mine. This process, which failed at the Elizabeth Mine, was used successfully at Pike Hill in 1906 and 1907. The mine workings of the Pike Hill mines were close together and left a complex landscape with indistinct and overlapping boundaries between the areas of activity. This landscape includes barren areas, mine openings, materials handling features, small piles of mill tailings, masonry foundations, and large metal artifacts.

Today the Pike Hill Mines site includes considerable archaeological and some structural remains, but no standing buildings remain from the small village that grew around the mine, or the blacksmith shop, office/laboratory, wash house, cobbing house, school, tenement house and several other buildings associated with early-twentieth-century milling, flotation and magnetic separation plants. The area is bisected by a logging road and waste rock has been moved to extinguish fires. There is less written historical and technological information about the mining activity on Pike Hill than there is for the Ely or Elizabeth mines. The sites of the early-twentieth-century flotation experiments and successful magnetic separation plant have the potential to reveal information about the layout and processes at these facilities. The site only included mining and some milling and was worked in a limited way for a limited period of time and lacks the resources to interpret as full a range of process and technology as either the Ely or Elizabeth sites. Pike Hill is physically remote and privately owned.

Summary of Significance of Orange County Copper Mines

The three mine sites in the Orange County Copper Belt that are discussed in this supplemental report operated at various times between 1809 and 1958, and made Vermont the largest copper-producing state in the U.S. for part of the 1870s. These mines contributed copper for conflicts from the Civil War to the Korean War, and were the scene of technological advances and labor strife. They all left legacies in the form of unusual historic landscapes and associated features, some that are common to all three mines, and some that are unique to one mine, or to mines in Vermont, New England, the Appalachians, or even the United States. Comparisons between the three mine sites are useful for assessing their relative integrity and archaeological and interpretive value. Each site, however, is different and possesses its own unique history, resources and values. Assessment of impacts and decisions about actions should be made within the context of each individual mine.

Of the three Orange County copper mines, the Elizabeth Mine at South Strafford operated over the longest period of time, produced the highest tonnage of copper, and left the largest and most complex mining landscape. Unique to the Elizabeth Mine are the copperas production area, the World War II-era landscape including TP 1, TP 2, and the intact cluster of mine plant buildings with rare flotation mill. The site is also unique among the three mine sites for its multiple smelting sites, including the early 1830s site and intact 1880s Sargent Brook site.

The Ely Mine site is significant as the archaeological remains of a nineteenth-century industrial complex and community site. It is unique in the Vermont Copper Belt for the remains of the massive smelter plant and stone slab smoke flue. It is also significant for its clear, linear progression of the mining process as expressed in the surviving landscape.

The Pike Hill mines were important for their contribution to the Ely Mine's production. It is unique in the Vermont Copper Belt as the site of successful magnetic separation efforts.

Recommendations

From a historic preservation standpoint, the best cleanup alternatives for resources of archaeological value are those that avoid impacts altogether by isolating critical archaeologically sensitive areas, or that combine site avoidance with an archaeological data recovery component for those areas that cannot be avoided. The planned cleanup options have the potential to impact historic landscape values of TP 1, TP 2 and TP 3. The best cleanup alternatives for resources of visual landscape value are those that retain and/or recreate the basic formal elements of the historic resource, including size, mass, shape, geometry, color, and texture. Retention of these areas and qualities also offers a highly advantageous result in terms of future uses for the mine, if those are to include an environmental and/or historic interpretive component. The presence of an unusual site like the Elizabeth Mine where the hand of man upon the landscape is so starkly obvious also has great potential value for environmental education.

The background research conducted for the supplemental report has determined that there is a strong likelihood that archaeological deposits related to the late nineteenth and early twentieth-century industrial activities at Elizabeth Mine exist under TP 1 and TP 2. The majority of these resources are most likely deeply buried up to 110 ft below surface, and proposed grading of the tailings would not likely impact the physical integrity of these deposits. However, the southwest tip of TP 1 and the north tip of TP 2 are particularly sensitive archaeological resource areas that could contain remains of the Tyson mill and blacksmith shop sites dating to ca. 1900. Should ground disturbances occur in these areas as part of the initial clean-up phase, further historic and archaeological research may be warranted in consultation with VT SHPO. This research would include additional documentary records studies along with field survey and excavations to locate, identify, and evaluate significant archaeological resources that may be affected by the proposed cleanup activities.

Additional documentary research is needed to assess the potential for the presence of pre-mining period resources, to determine the presence of additional expected mining resources, and to more precisely locate known resources in areas that are slated for cleanup activities. Field survey and excavations may also be warranted in areas slated for associated cleanup activity such as construction sites, staging locations, batching plants, borrow pits, and associated transportation routes, truck turnarounds, etc.

A fieldwork component needs to be included in any subsequent studies of the Elizabeth Mine site undertaken as part of the planned cleanup work. Fieldwork is critical to assess the character, condition, integrity and visibility of the areas and their specific resources, to locate expected resources, and to allow more definitive delineation of these areas and assessment of their interpretive value. Field survey should include GPS mapping of the entire site to generate an overall Elizabeth Mine Historic Resources Base Map that precisely locates and delineates all areas and resources in relation to known natural and man-made features. This activity should also include detailed mapping of the World War II-era mine plant buildings and associated features. Careful mapping of all historic features on TP 3 should be integrated into any geochemical surveys and mapping of that area to correlate contamination sources and other data with the locations of features to better understand how the copperas works functioned and to serve as a basis for decisions about cleanup activities. Documentation of the existing conditions at the Elizabeth Mine may require innovative approaches such as color photography, video, or other methods to capture the color, scale and other important formal elements of the landscape, in addition to the conventional documentation methodology including black-and-white photography, mapping and narrative history. The social history of the mine, which was not addressed in this report, is another area that requires further research and documentation.

Any future archaeological studies at Elizabeth Mine should also include close coordination and communication between the cultural resources team and project design and engineering staff at Environmental Protection Agency, Army Corps of Engineers, Vermont Department of Environmental Conservation, Agency of Natural Resources, and Arthur D. Little Inc. as cleanup plans advance toward the design phase.

1.0 Introduction

This report provides information supplemental to the *Statement of Limits, National Register Eligibility, and Potential Resources in the Proposed APE, Elizabeth Mine, South Strafford, Vermont*, prepared by Hartgen Archaeological Associates, Inc. (October 2000), which is bound with this report. The supplemental information was generated to respond to report comments made by the Vermont State Historic Preservation Office (VTSHPO), the community and other official commentors. PAL was contracted by Arthur D. Little, Inc., on behalf of the Environmental Protection Agency (EPA), to respond to these comments in accordance with Section 106 of the National Historic Preservation Act of 1966, as amended.

This report partially fulfills EPA's compliance with Section 106 of the National Historic Preservation Act and its' implementing regulations, 36 CFR Part 800. It identifies and evaluates the historic properties that may be affected by EPA's actions. Additional areas of research are identified and recommendations are made for future consideration of the historic properties. When the final alternatives for EPA's action are selected and all interested parties have been consulted, a Memorandum of Agreement will be executed.

Elizabeth Mine is a designated National Priorities List (Superfund) site, and as such, the EPA is coordinating the hazardous material cleanup of the site to protect human health and the environment. The EPA determined that the Elizabeth Mine Site is eligible for inclusion in the National Register of Historic Places, based on the documentation provided in the Hartgen report (letter from E. Hathaway to E. Wadhams, dated January 10, 2001). The VTSHPO concurred with the EPA's finding of National Register eligibility and concluded that the site is eligible as the Elizabeth Mine Historic District, although the districts formal boundaries have not yet been determined (letter from E. Wadhams to E. Hathaway, dated March 9, 2001). While the site or districts boundaries are currently unknown, the EPA recognizes that any proposed cleanup action at the Superfund site has the potential to adversely affect some portion of the historic property. The current study area for cleanup includes the tailings, waste rock, slag, and heap leaching piles from the former copper and copperas production activities as well as a cluster of World War II-era mine buildings, two open cuts, underground mine workings, and the drainage from the underground mine workings.

1.1 Scope

PAL served as the principal investigator for the report to supplement the *Statement of Limits, National Register Eligibility, and Potential Resources in the Proposed APE, Elizabeth Mine, South Strafford, Vermont*, prepared by Hartgen Archaeological Associates, Inc. (October 2000). PAL's scope of work consisted of three primary tasks related to establishing the sites significance and responding to comments received by the VTSHPO and official commentors. These tasks involved: 1) background research in appropriate historic archives, consultation with persons knowledgeable about the history of the mine and the copper mining industry; and review of materials collected by Hartgen Archaeological Associates, Inc.; 2) the development of applicable historic contexts based on the background materials to support the National Register eligibility of the site as well as to identify the research value of various known and potential elements; and 3) to produce this supplemental report that presents the historic contexts and site resource descriptions along with management recommendations for the proposed cleanup action and future cultural resources studies. These tasks were undertaken to assemble more detailed historic information about the site to facilitate decision making, to facilitate determinations of effect on specific parts of the site and specific resources at the site, to better understand its specific historic values as cleanup alternatives are chosen and designed, and to help identify appropriate treatment for specific parts of the site and specific resources should they be impacted by cleanup actions.

1.2 Site Description

The Elizabeth Mine (Vermont Archaeological Inventory VT-OR-28), established in the early nineteenth century and operated until the mid-twentieth century, is located in the town of Strafford in Orange County, Vermont. It lies approximately one-half mile south of the West Branch of the Ompompanoosuc River, a tributary of the Connecticut River, in the rugged uplands of east-central Vermont. This section of Orange County hosted mining activity in the approximately 20-mile long Copper Belt, and by the late nineteenth century was the location of several other mining operations, including the Ely Mine in Vershire (VT-OR-14) and Pike Hill Mines (Eureka and Union) (VT-OR-27) situated in the town of Corinth. Today, Elizabeth Mine contains major mining landscape features, numerous standing structures, and the aboveground and buried remains of structures and features related to several periods of mining operations at the site. The surviving historic landscape related to the mine could exceed 850 acres of land focused on the core area of mining activity, although the total land area associated with the Vermont Copper Company in the 1950s was about 8,000 acres.

1.3 Authority

The cultural resource investigations for Elizabeth Mine are being conducted to fulfill the EPA’s obligations under Section 106 of the National Historic Preservation Act (NHPA) of 1966, as amended (16 U.S. C. 470f) that requires federal agencies to take into account the effects of their actions on historic properties and to consider ways of avoiding, minimizing, or mitigating adverse effects. This supplemental cultural resource report follows the guidelines contained in the Secretary of the Interior’s *Standards and Guidelines for Identification* and the guidelines of the Vermont Division of Historic Preservation (VDHP).

1.4 Project Personnel

PAL of Pawtucket, Rhode Island served as the technical principal investigator for the project. PAL project staff include A. Peter Mair II, project manager; Matthew A. Kierstead, industrial historian; and Suzanne G. Cherau, senior archaeologist. Background research and report preparation were completed from February to May 2001.

2.0 Methodology

2.1 Goals/Objectives

The primary goal of the supplemental cultural resource support services provided by PAL was to fill data gaps and address reviewer comments on the previous report, *Statement of Site Limits, National Register Eligibility, and Potential Resources in the Proposed APE, Elizabeth Mine, South Strafford, Orange County, Vermont* (Hartgen 2000). In order to accomplish this goal, PAL undertook a comprehensive search for historic materials pertaining to the Elizabeth Mine and other associated mines. This background search located and gathered historic materials including literature, maps, and photographs in the collections of various archives and individuals. This material was then reviewed and evaluated for its applicability and usefulness for this report. The selected information was then used to develop a broad historic context statement that places the Elizabeth Mine into several specific historic contexts including copper mining in the Appalachians and the Vermont Copper Belt.

The contexts also include a discussion of process and technology at the Elizabeth Mine, particularly copperas production, and the evolution of the resulting mining landscape. As a result of this research, PAL was able to provide a more thorough description of the current landscape, known visible features, expected resources, preliminary physical integrity. PAL was also able to make preliminary evaluations of the research value and interpretive potential of specific areas within Elizabeth Mine. This report also places the Ely and Pike Hill mines into their historical context, presents their morphology and evaluates their historic resources in similar terms. The report includes a preliminary assessment of the relative values of all three Orange County copper mines and identifies the qualities that make the Elizabeth Mine distinctive.

The Elizabeth Mine site is complex and represents approximately 160 years of industrial activity (Figure 2-1). Some of this activity took place at isolated areas during narrow time frames, and is easy to understand and evaluate. However, much activity took place in the same areas over longer periods of time and has a more complicated land use history. Included in the latter category are the three main areas identified for response activity. These areas have been given shorthand names for the purposes of discussion. They are the large tailings pile that fills the valley between Copperas Hill and Grove Hill, or TP 1; the smaller tailings pile to the southwest, or TP 2; and the copperas production area on the steep east flank of Copperas Hill, or TP 3. These large, highly visible landscape elements resources are understood to be significant historic resources for their potential archaeological research and/or visual landscape value, and their history is discussed in Chapter 4 - History and Resources of the Elizabeth Mine.

The Elizabeth Mine was also the scene of no less than nine copper ore smelting campaigns and six ore concentration milling phases, some of which took place in remote areas, with some occurring in and around the tailings pile areas. Some of these activities were technologically significant, and others were conventional for their time; some are located in areas slated for response activities, and some are not; and some have visible remains that retain a high degree of integrity, while others were destroyed or buried by later mining activities. The history of these operations is also included in this report, and the status of their remains is assessed. A site as large as the Elizabeth Mine contained ancillary and peripheral buildings, structures, transportation routes, and domestic sites that may have escaped documentation, archaeological evidence of which could be located anywhere on site (see further discussion of resource potential in Chapters 4 and 7).

2.2 Information Sources and Acknowledgements

PAL consulted a wide variety of information sources during the background research. These sources can be divided into several categories. The most valuable contributions were made by mining and industrial historians who generously shared their collections, knowledge, and time, including Appalachian mining historian Collamer M. Abbott of White River Junction, VT; Johnny Johnsson of Finksburg, MD; and Victor Rolando of Bennington, VT. Important local informants and contributors included Gwenda E. Smith, historian/curator, Strafford Historical Society; Sheldon Novick, scholar in residence, Vermont Law School; James Condict, a former Elizabeth Mine employee, and Robert J. Walker of the Elizabeth Mine Study Group. The materials sent by these people included key documents from the Collamer Abbott Collection archived in the Special Collections Department of the Bailey/Howe Library at the University of Vermont in Burlington, and relevant materials formerly located at Dartmouth College in Hanover, NH, and now stored in Strafford. Additional documents relating to Orange County and Appalachian mining already in the private collection of report author Matthew A. Kierstead were also consulted. Additional sources of information consisted of previous Elizabeth Mine reports generated by Arthur D. Little, Inc. and EPA, and *Statement of Limits, National Register Eligibility, and Potential Resources in the Proposed APE, Elizabeth Mine, South Strafford, Vermont*, prepared by Hartgen Archaeological Associates, Inc. (October 2000).

Representatives from United States government agencies, including Jane Marie Hammarstrom and John Slack at the United States Geological Survey and Dawn Bunyak at the National Park Service; identified material. Information was also located through Vermont state agencies including the Vermont Geological Survey, the Vermont State Historic Preservation Office and the Office of the Secretary of State. Regional and local historical organizations including the Vermont Historical Society, the Strafford Historical Society and the Elizabeth Mine History Group were also useful sources of archival background material and historical information. Computerized databases including *Georef* and the Vermont Mineral Resources Data System (MRDS) were also useful for identifying relevant literature.

This search resulted in the assemblage of a large volume of archival material. PAL determined through sorting the material and consulting with other mining and local historians that the most relevant background material had been collected. PAL then undertook a process of characterizing and organizing the material according to its usefulness and association with the historic contexts identified for the report. As the archival material was collected, it was entered into a project Historical Materials List divided into categories by literature type.

The volume of historical and scientific literature associated with the Elizabeth Mine and Orange County mining in general is considerable. Fortunately an excellent history of the Elizabeth Mine, and copper mining in Orange County in general, exists in the form of "Green Mountain Copper", an unpublished manuscript written by Appalachian mining historian Collamer M. Abbott in 1964. This manuscript is currently located in the Collamer Abbott Collection in the Special Collections Department of the Bailey/Howe Library at the University of Vermont in Burlington. Abbott devoted a considerable part of his life researching and writing about Appalachian and Vermont copper mining and "Green Mountain Copper" represents a thorough and considered analysis and synthesis of a wealth of primary and secondary information. It is fortunate that this work has been done. Information from "Green Mountain Copper" forms the backbone of the historical context chapters on the three mining sites discussed in this report. Citations in the mine history chapters refer to the Abbott manuscript. Readers intent on following the historiographical trail to determine Abbott's sources may consult the reference notes at the end of his manuscript. Since Abbott's manuscript was written, additional information and interpretations have emerged. Review and synthesis of Abbott's sources and the new information is outside the scope of this current report, which relies largely on Abbott's work. This report attempts to note all major phases of technological, and therefore, landscape development at each of the Orange County copper mines. However, it is possible that some minor developments at the mines have been omitted and should be the subject of further research.

2.3 Report Structure

The supplemental report is organized into seven chapters, with the first two consisting of the project introduction and methodology. Chapter 3 presents the mining history for the appropriate national, regional, and state contexts. Chapters 4 through 6 present the histories of the Elizabeth Mine, Ely Mine, and Pike Hill Mines sites along with their respective historic and landscape resources and interpretive values. Historic maps and photographs illustrating key periods and/or areas of the mine sites are included at the end of each section of this report.

Chapter 4 consists of an Elizabeth Mine historical narrative and site description divided chronologically into phases beginning in the pre-mining period of the early nineteenth century, including the major phases of mining and ore processing at the site, and ending with the history of the mine since its closing in 1958. Chapter 4 also includes a discussion of the historical significance, physical integrity, archaeological research potential, physical landscape value and interpretive potential of the various areas at the Elizabeth Mine.

Chapters 5 and 6 discuss the history and known resources at the Ely Mine in Vershire and the Pike Hill (Eureka and Union) mines in Corinth, respectively. These historical narratives are less detailed than the Elizabeth Mine history, and concentrate on the development of the landscapes and historic features to allow comparison with the Elizabeth Mine.

Chapter 7 presents conclusions and recommendations for further cultural resource evaluation tasks including field survey, additional research, and further resource evaluation.

2.4 Historic Resource Mapping

The scope of the supplemental report did not include a fieldwork component, which is planned for subsequent phases of historic and archaeological study at the site. Accordingly, the historic context and site description sections of the report do not include definitive information about the character, physical condition, and industrial archaeological integrity of individual site elements at each of the mines. In addition, no tabular summary of individual site elements or graphics depicting site locations are included in this report. For approximate historic resource locations, readers should refer to the annotated historic map overlays included in *Statement of Limits, National Register Eligibility, and Potential Resources in the Proposed APE, Elizabeth Mine, South Strafford, Vermont*, prepared by Hartgen Archaeological Associates, Inc. (October 2000) which is bound with this report.

2.5 Prehistoric Native American Resources

The current study does not include information relating to the prehistory or pre-mining history of the Elizabeth Mine Site. If information relating to the use of the site by Native Americans is identified, this matter will be fully evaluated as part of the 106 process. With respect to the potential mining of copper by Native American populations, the geochemical nature of “Appalachian sulfide” ore deposits does not lend itself to the formation and deposition of pure, workable “native” copper as found in the Michigan copper mining district. Therefore, at this time, it seems unlikely that there was extraction and processing of metallic copper during the prehistoric period. A small number of unsubstantiated native copper finds in Vermont, including ones at Strafford and Vershire, were reported in the mid-nineteenth century, but no specimens exist and there is some debate as to whether these finds were indeed naturally-occurring or “salted” for purposes of deception (Levine 1999:193). No smelting of metallic sulfide ores by Native Americans has been documented in the United States.

3.0 Appalachian Mining History Context

3.1 Introduction

The history of mining spans thousands of years of global activity. The Elizabeth Mine needs to be placed into a focused historical perspective to provide appropriate context for the significance of its landscape and resources to be evaluated. The Elizabeth Mine is one of three major copper mines that exploited an "Appalachian" type, metamorphosed sediment-hosted metallic sulfide ore deposit in Orange County, Vermont, during the nineteenth and twentieth centuries (Figure 3.1). This narrative places the Elizabeth Mine in the contexts of major northeastern U.S. mining activity, U.S. copper mining during the nineteenth and early twentieth centuries, Appalachian metallic sulfide mines, and extractive industry in Vermont. This narrative ends with a brief summary of copper mining in the Orange County, Vermont, Copper Belt, which includes the Elizabeth Mine in South Strafford, the Ely Mine in Vershire, and the mines on Pike Hill in Corinth. The history and historic resources of each of these mine sites are further explored in subsequent chapters.

3.2 Mining in the Northeast United States

Metal mining is not traditionally associated with the history or cultural landscape of the northeastern U.S. The history of American extractive industry is dominated by the romance and richness of mining in the American West that ranges from the drama of the 1849 Gold Rush to the massive open-pit mines of today. Unfortunately there is a limited body of secondary historical literature that covers the history of metal mining in the Northeast. Unlike the West, where the scale of mining operations and the arid climate make mining landscapes obvious, the majority of historic mining resources in the Northeast are often located in smaller, localized mining districts that are far less obvious than their counterparts in the West because of their age, limited development, heavy vegetation cover, and subsequent land use. The Appalachian Mountains and adjacent areas of the Northeast, however, have included a number of large mining operations and do have a heritage of extractive industry that has left dramatic evidence in the form of historically significant landscapes and archaeological and architectural remains. The Elizabeth Mine, a comparatively large operation for an eastern metal mine, is a rare historic mining resource in the region as it includes considerable architectural remains and a relatively undisturbed landscape and archaeological context.

The geology of the Northeast, and the Appalachian Mountain trend in particular, is complex and includes rock units of widely varying ages and depositional environments. The Appalachian Mountain trend stretches with minor interruptions from Maine to Alabama and includes the Green Mountains of Vermont. These mountains are made up of folded metamorphosed sedimentary and volcanic rocks that were assembled and subjected to varying degrees of metamorphism during several continental collisions over the course of several hundred million years. The Northeast region hosts a wide variety of economically significant mineral deposits including industrial minerals, building stone, aggregate, fuel, and many classes of metallic ores. The following discussion of historic mining activity is by no means exhaustive and is only intended to indicate the mineral richness of the region through several examples of major mining commodities and districts.

The word "Appalachia" is almost synonymous with coal mining. The Appalachian coal measures include world-class deposits of bituminous (soft) and anthracite (hard) coals. The anthracite coal is confined to four fields in east-central Pennsylvania, the largest anthracite coal deposits in the world. Before the introduction and spread of oil and natural gas, Pennsylvania anthracite was the primary domestic heating fuel in the Northeast. The anthracite industry is largely defunct, but has left its mark on the communities and landscape of the region. The bulk of the coal mined in the Appalachians today is bituminous coal. The numerous overlapping coal beds stretching from central Pennsylvania to central Alabama include coal of many different ranks suitable for many industrial processes including production of steam for power or distillation for chemicals. The Pittsburgh Seam in southwestern Pennsylvania is so well suited to conversion to pure carbon coke fuel that it was a major factor in the dominance of the American steel industry in the twentieth century, and is considered one of the most valuable mineral deposits in the world. Coal mining leaves distinctive landscapes including shaft headframes, drift entrances, open cuts and pits, washing plants, and slack piles. The "coal patch" company mining town is a common architectural and social environment associated with this industry in the central and southern Appalachians.

Less a part of the cultural landscape, but nonetheless a presence in the Northeast and Appalachians, is metal mining. Iron has been mined in the Northeast since colonial times. The seventeenth- and early-eighteenth-century ironworks were smaller and relied mostly on marginal quality bog iron ores. By the mid-eighteenth century, blast furnaces began to smelt higher-quality ores including hematite found in western New England and eastern Pennsylvania and magnetite mined in the Reading Prong formation stretching from eastern New York through New Jersey to northeastern Pennsylvania. Some of the larger magnetite mines, including the Grace and Cornwall in Pennsylvania and many in New Jersey and eastern New York continued to be important sources of rich magnetite iron ore after the discovery of the hematite mines of the Mesabi Range and other iron ranges of the western Great Lakes. In the Precambrian Shield of the New York state's Adirondack Mountains, magnetite iron ore was mined until the last decades of the twentieth century. This region includes the Benson Mine at Star Lake, the world’s largest open pit magnetite mine, and the MacIntyre Mine at Tahawus, the world’s largest open pit titanium (ilmenite in magnetite) mine. These mines have been abandoned, leaving vast industrial landscapes including tailings, waste rock, modern-era mill complexes. Iron ore is no longer mined in the eastern U.S. Zinc was mined in the Franklin-Ogdensburg area of New Jersey, which hosts one of the largest and geologically enigmatic zinc mining districts in the U.S. Zinc deposits are not widespread in the Northeast, however, this one mining district was once a major U.S. source of zinc ore for the New Jersey Zinc Company. Technological advances in processing the ore during the nineteenth century led to the construction of a massive smelter complex at Palmerton, Pennsylvania, at the start of the twentieth century. Other zinc ores came from Friedensville, PA, and Austinville, VA. Underground zinc mines in the St. Lawrence River valley in upstate New York are some of the most productive in the U.S. today.

These are only a handful of examples of some of the larger or more historically significant mines associated with the more common industrial metals. The Northeast and Appalachians hosted hundreds of smaller metal mines and literally thousands of prospects. Quarries for building stones, industrial minerals and aggregate constitute another class of extractive industry that is too broad to deal with here in a regional context, but will be discussed briefly in the section on Vermont extractive industries.

3.3 Copper Mining in the United States from Colonial Times to the Mid-Twentieth Century

The first American settlers prospected for minerals for the manufacture of metal goods and to raise capital. Precious metals were the first sought, but significant quantities of gold were not found until the southern gold rush of the late 1820s. The first known American copper mine, the Endecott Mine, was located at Topsfield, Massachusetts, and was not a successful producer. During the seventeenth and eighteenth centuries finished copper goods were imported from Europe. European copper smelters were paying high prices for copper ore, however, and some was found in the colonies and shipped to Europe make bronze and brass, which were important for shipbuilding, ordnance and precision machinery. Most of the copper ore encountered in the colonies was of the sulfide variety, which was pyritic and more difficult to smelt. Large sulfide copper orebodies remained unexploited until the early nineteenth century, when they were shipped to Swansea, Wales, where the sulfide ore smelting process had been perfected (Young 1983:117-119).

The earliest colonial copper mines worked carbonate copper ores, which were easier to smelt. These ores were associated with the Jurassic lava flows of central and western Connecticut and the Watchung Mountains of New Jersey. In 1659, Dutch explorers reported copper at the Delaware Water Gap, where the small Pahaquarry mine was developed, but closed by 1664. The most productive New Jersey mine was the Schuyler Mine, discovered in 1713. Arent Schuyler mined about 100 tons of ore annually and sent it to Holland for smelting. This mine was a substantial operation for its time, with a 100 ft shaft, imported Cornish miners, and use of explosives. It bears the distinction of the site of the first steam engine built in America, a Newcomen engine, which was used to pump water from the mine. The mine ultimately shut down in the 1770s. Several other Watchung mines operated during the eighteenth century. Most of the ore was shipped to Europe but a small custom smelter was erected at Belleville in 1793. The earliest and most productive colonial copper mine in New England was started in

Simsbury, Connecticut, and shipped perhaps 500 tons of ore in 1714. The Simsbury mine later served as a Tory prison and a Connecticut state prison until 1823. Several other copper mines were found in the Naugatuck River valley between 1770 and 1820. In Maryland, ore from the Mineral Hill and Liberty mines in Carroll County was smelted and the Liberty Mine is considered the most productive American copper mine to have operated during the Revolutionary War (Mulholland 1981:39, 43-47; Young 1983:121-125).

The colonial copper industry suffered because of unfavorable economic systems, a lack of skilled labor, and poor transportation. The Revolutionary War and post-war conflicts and trade restrictions disrupted copper production and importation. By 1800 the U.S. Navy was demanding copper sheathing for ship hulls, but there was no domestic copper mining or smelting industry to satisfy the demand. The trade embargoes of the War of 1812 provided stimulus for domestic metals production, but copper rolling mills in Boston, New Jersey and Baltimore could not obtain enough metal or smelt Appalachian ores. The first notable post-Revolutionary War copper discovery was made at the Elizabeth Mine, but the copper values were not realized until the 1820s when small amounts of copper were precipitated on scrap iron as “copper mud,” rather than smelted from the ores. Some smelting was carried out at South Strafford in the 1830s, with some significant technical achievements, but the operation was not sustainable (Abbott: 1971:426; Young 1983:126-129).

After the 1820s the situation for copper smelting changed rapidly and by 1840 protective tariffs were in place, and skilled miners and smeltermen could be recruited. Transportation and fuel were still major issues facing exploitation of Appalachian sulfide copper, but by 1845 Pennsylvania anthracite coal was available, and railroads and canals had penetrated the interior. By the 1840s, many of the British copper mines were exhausted and new copper mines were opened up in South America. During the 1840s East Coast custom smelters were opened at Boston, Baltimore and New Jersey. These smelters processed imported South American and Cuban ores as well as ores from Ducktown, Tennessee; Ely, Vermont; and a host of smaller sources that became important suppliers of copper during the second half of the nineteenth century (Young 1983:130-132.). The Civil War provided a boost to northern mines such as the Ely, but shut down southern mines such as those at Ducktown. After the Civil War several important southern mines, including Ducktown, Ore Knob in North Carolina, and Stone Hill in Alabama, enjoyed increased prosperity. By the 1850s, however, Michigan copper, which had become a major source, was threatening Appalachian sulfide copper mines. By the 1880s Michigan and new mines in Montana and Arizona eclipsed Appalachian copper, which would not be mined profitably again until the application of modern methods in the mid- twentieth century.

Copper from the Keweenaw Peninsula of northern Michigan was used and traded by Native Americans, and was reported by seventeenth-century French Jesuit missionaries (Mulholand 1981:41). In 1841, Douglass Houghton discovered a rich copper deposit there and opened the Cliff mine four years later. Michigan ores contained native copper, nearly pure metal that required physical separation, but did not require the multiple energy-intensive smelting steps to remove sulfur as did sulfide ores. Michigan copper began to arrive on the market in 1845. Only 51 tons were produced in 1848. Michigan copper mining grew at a rapid pace, and by 1850 the region was producing 88 percent of the copper made in the country. In 1855, 2,900 tons of copper was produced in 20 underground mines, and in 1860, 6,000 tons was produced. In 1860 the first smelter near the mines was built in Hancock, Michigan. The Calumet & Hecla Mine was developed in the late 1860s and by 1869 was producing half of the district's copper alone. By 1871 Michigan was making 91 percent of the copper mined in the U.S. Because of this competition and elimination of protective tariffs, the East Coast smelters waned in the 1870s (Hyde 1998:36, 42; Young 1983:136).

Just as eastern copper was earlier eclipsed by Michigan's production, in the 1880s Michigan slowly began to lose ground to a new threat, the copper mines of Butte, Montana, which gained market share in 1887. Michigan continued to produce, and even increase, its copper production. It produced 50,000 tons in 1890 and a peak of 133,000 tons in 1913, but slipped to 81,000 tons by 1920. Despite these figures, it was outstripped by large, low-cost producers in Montana and Arizona, and its 1920 production figure represented only 13 percent of U.S. output (Hyde 1998:49, 55-60).

Butte Montana, began as a silver mining camp in 1874. Although the presence of copper was known, it was not considered important at first. In 1882, the silver ore at the Anaconda Mine ran out, but graded into the richest copper deposit then known in the world. The vein was up to 100 ft wide and assayed as much as 50 percent copper. The Anaconda Mine spelled the end of Michigan's copper dominance. Several other rich mines sprang up in Butte, and were soon consolidated by a handful of colorful entrepreneurs. By 1885 Montana produced 41 percent of U.S. copper. Several smelters were built, including a large one at Anaconda, 26 miles west of Butte. By 1885, the Anaconda Mine produced 50 percent of Montana's copper, and did so until the late 1890s. Butte copper producers initially produced copper matte that was shipped east to smelters. They later invested heavily in electrolytic copper refining, which strengthened Butte's competitive edge over Michigan, which had deeper mines, leaner ores, and more expensive refining operations. The Washoe Reduction Works, built at Anaconda in 1902, could process 15,000 tons of copper ore per day at 39 percent lower costs than previously attained. Butte was the dominant American copper camp into the early twentieth century (Hyde 1998:67–102).

Arizona, which eventually became the biggest copper producing state in the U.S., began its rise during the 1880s. Arizona was not opened up to development until the 1870s because of hostilities with Native Americans and a lack of railroad transportation. The turning point was the development of the rich Copper Queen underground mine at Bisbee in the 1880s. In 1874, Arizona produced 400 tons of copper, but by 1882 it produced 9,000 tons, second only to Michigan. Four major Arizona mining districts emerged, at Clifton-Morenci, Globe, Jerome, and Bisbee, each dominated by a single company. All operated underground mines on rich vein deposits. From 1882 to 1884, Arizona rose to produce 20 percent of U.S. copper. In 1900, Arizona, with just a half-dozen big mines, gained preeminence over Montana. By 1920 Michigan and Montana made only 20 percent of U.S. copper, and Arizona made nearly half the total (Hyde 1998:112–126).

The American West emerged as a major world copper producer in the early twentieth century because of the application of mass production techniques to mining. Once the high-grade vein deposits were worked out, miners turned to the low-grade, “porphyry” deposits of disseminated sulfide ores. Mining engineers such as Samuel Jackling, who developed the massive Bingham Canyon mine near Salt Lake City in Utah, applied new open-pit mining techniques using steam shovels and railroads, and new mechanized flotation ore separation techniques, on a scale that could profitably extract the copper content. These methods spread throughout the West and were applied to disseminated orebodies in Arizona, Montana, Nevada, New Mexico, Utah, and elsewhere, and are still in use in the region today.

Copper was mined in the Eastern U.S. for at least 275 years. Between 1760 and 1844, eastern production was roughly 3,000 tons. The region’s production from 1844 to 1962 was about 965,000 tons, about two percent of U.S. production for the period. Ultimately copper production in the east was minuscule compared to the output of the U.S. and even some individual U.S. mines. Although the large operations of the American West have dominated U.S. copper production since the early twentieth century, several eastern U.S. copper mines were reopened and worked profitably at times when wartime demand warranted it or prices were high enough, and they could be operated efficiently with proven technology. Several Appalachian sulfide mines, including the Elizabeth Mine, experienced their greatest phase of productivity during the second half of the twentieth century (Abbott 1966: 79-80).

3.4 Appalachian Sulfides

One of the major classes of metallic ore deposits in the eastern United States is the group known as the Appalachian sulfides. These ore deposits consist of iron sulfide in the form of pyrite or pyrrhotite, often mixed with lesser quantities of copper, usually in the form of chalcopyrite, and sometimes zinc, lead and trace amounts of other, sometimes precious, metals. These orebodies are often pod-like, lenticular, or tabular in shape, and often swell and pinch or form overlapping lenses. They are generally massive and fairly sharply bound by their schistose host rock, as they were deposited at the same time. The genesis of Appalachian sulfides was debated by geologists for centuries until the advent of plate tectonic theory and the discovery of undersea hydrothermal vents. These orebodies are now generally understood to have been deposited on ancient seafloor as thick sulfide ore beds by hydrothermal vents that precipitated metals that had been leached from undersea magma by hot circulating seawater. These sulfide beds were eventually buried by sediments and incorporated into new continental crust in accretionary prisms where ocean crust was being subducted. These sedimentary and volcanic rocks were then included and altered in the roots of folded mountain ranges, uplifted, and eroded, exposing them for discovery. These metallic sulfide ore deposits have been further classified into subgroups according to their original depositional environment. Geologists consider the Elizabeth Mine and other Orange County copper deposits to be examples of what is called a “Besshi” type massive sulfide deposit, named for its type locality in Japan. This class of hydrothermal seafloor deposits are thought to occur where sediment-covered crust is pulling apart at oceanic spreading centers (Zierenberg, et al:1993:2070). Appalachian sulfide deposits stretch from Alabama to Maine, and continue into New Brunswick. Ore deposits of this type are found all over the world, and are being deposited in submarine environments today.

A review of Appalachian sulfide mines is helpful to put the Orange County copper mines in historical perspective.

Appalachian pyrites occur in Cleburne County, Alabama, near the southern terminus of the Appalachian mountain chain. The only paying copper mines in Alabama were at Stone Hill, and at the nearby Smith Mine. Copper was discovered there in 1874, and a small smelter made pig copper until 1879. The mine was briefly reopened in 1896 and the ore was shipped to New Jersey to be smelted. In Georgia, the Seminole Mine in the northeast part of state was worked until about 1900 for copper and gold, and several other pyrite deposits were mined for manufacturing sulfuric acid.

The largest, most productive and longest-lived Appalachian sulfide mining district was at Ducktown in the extreme southeast corner of Tennessee. In 1843 a cluster of sulfide ore outcrops were discovered in a belt 2 miles wide and 4 miles long. The deposits were worked intensively during the 1850s, when smelters were built and a refinery and rolling mill was built at Cleveland, Tennessee, by the Union Consolidated Copper Company. Activities were suspended during the Civil War, and resumed in 1866. By 1877 the mines shut down because of changes in the ore, lack of adequate fuel and transportation, and technological problems with smelting the ore. In 1890, a railroad line was built to the mines and they reopened with new smelting works. The smelting process included open-air roasting of sulfide ores that released sulfur dioxide gas that denuded the entire surrounding valley. In 1906, the State of Georgia won a suit with the Ducktown Sulfur, Copper & Iron Company over the smelter fumes. The company switched to a pyritic smelting process and converted the sulfur dioxide gas to sulfuric acid in a landmark early American acid plant. In 1936, the mines consolidated under the Tennessee Copper Company. In 1960, the company was mining 1.5 million tons of copper ore from five shafts, and realized all the values in the ore including copper, iron, zinc, sulfur and others. These were the only deep shaft US copper mines east of Mississippi River when they finally shut down in 1987. Part of the remaining mining landscape is now being preserved in an unreforested state by the Ducktown Copper Mining Museum to interpret the effect of mining and smelting on the Copper Basin environment.

Another large Appalachian sulfide mine, and the only other one comparable to the Elizabeth Mine in size, was the Ore Knob Mine in Ashe County, North Carolina. Ore Knob was discovered before the Civil War. It was worked intensively between 1871 and 1883 by a group of Baltimore investors. Twenty-five million lbs. of copper ore were mined from 11 openings and one main shaft along a 2,800 ft long outcrop. The works included Continental-style smelting furnaces. The mine was reopened in the late 1950s by Appalachian Sulphides, Inc., after that company shut down their operation at the Elizabeth Mine. The Carolinas included several small copper mines including the Gap Creek, Elk Knob, and Peach Bottom. The Fontana mine operated from 1926 to 1944 and produced 38 million lbs. of copper that was smelted at Ducktown. Virginia included five sulfide mine districts. The most extensive one was the Great Gossan Lead, a long, narrow outcrop that extends more than 20 miles through Floyd, Carroll and Grayson counties. It averages 20 to 40 ft in width, and expands to almost 200 ft in places. Most of the mining activity took place during the nineteenth century from open cuts and at least eight shafts, and the mine produced iron, copper and sulfuric acid from pyrite. Maryland hosted three small copper sulfide mining belts with half a dozen significant mines, most of which were operated by the Tysons of Baltimore. Pennsylvania also included a few small sulfide mines, including the Gap Nickel Mine, and a notable sulfide mine was located at Anthony's Nose, NY.

Appalachian sulfides were a notable source of metallic ores in New England. In Massachusetts, sulfide ores were mined in the "mineral belt" between Plainfield and Rowe, MA, which was briefly developed about 1900 and included the small Windsor Bush copper mine and Hawks zinc mine, and the Mary Louise copper mine, which included a small smelter on site. The Davis Mine at Rowe, however, was more significant as it was one of four major domestic sources of pyrite for sulfuric acid production at the end of the nineteenth century. This mine operated from 1882 to 1912, had three shafts, and reached a depth of 1,024 feet deep, making it the deepest underground mine in the state. Copper ore found in the pyrite was shipped to custom smelters. All of these sites are undisturbed and include collapsed shafts and building foundations. None of these sites are as extensive as the Elizabeth Mine or include standing structures.

New Hampshire hosted several nineteenth-century Appalachian sulfide mines. The Ore Hill zinc mine on the Appalachian Trail at Warren was operated from 1840 to 1870 for copper, zinc and sulfuric acid. It was reopened in 1884, 1900 and 1914. The mining landscape there has been insensitively reclaimed, spoiling its historic appearance. The West Milan pyrite mine was worked from the 1870s to 1886, and again in 1909, for feed material for sulfuric acid production for paper mills in Portland, Maine and upstate New York. The copper content was shipped elsewhere for smelting. Both of these sites include collapsed shafts and building foundations. Neither site is as extensive as the Elizabeth Mine. Across the Connecticut River from the Orange County, Vermont Copper Belt is New Hampshire's Ammonusuc gold mining district centered on the Bath and Lisbon area. This region hosts many small mine sites including the considerable remains of the Dodge Mine, which produced gold from copper sulfide ore mined from three shafts between 1867 and 1874.

Maine hosts several large Appalachian sulfide ore deposits. The iron-bearing material smelted in the Katahdin Ironworks blast furnace between 1846 and 1890 was the "gossan," or weathered cap of one of the largest known deposits of the iron sulfide ore pyrrhotite in the United States. The Blue Hill area in Hancock County hosts a dense cluster of sulfide ore deposits that were exploited in the "Maine mining boom" of the 1880s, when the town of Blue Hill resembled a western mining town and even published its own mining newspaper. Most of these mines were small. However, they include evidence of their Cornish mine workers in features including the unusual detail paid to squaring off openings and neatly disposing of waste rock. The Douglas Copper Mine at Blue Hill produced more than 2 million lbs. of copper ore between 1878 and 1884, enough to attract the Guggenheim-backed American Smelting and Refining Company to reopen the mine and build a 350 ft deep shaft, a mill and smelter there in 1918. The rare standing remains of an oval-hearth copper blast furnace still stand at this site, which includes roast beds and slag heaps.

During the 1960s and 1970s this mining district saw two large, modern mines open and close. The Black Hawk underground zinc mine first operated in the 1880s and again in 1917. In 1965, a 700 ft shaft was sunk and 10,000 ft of workings on three levels were developed before the mine was mothballed. In 1970, KerrAmerican reopened the mine, drove additional workings, and built a 1,000-ton per day flotation mill that produced zinc and copper concentrates. The mine closed in 1977 and left behind large concrete tanks and foundations. In 1968, at the site of the Cape Rosier Mine at Harborside, the Callahan Mine was opened to mine a copper-lead-zinc sulfide orebody. This mine grew into a 9.4 acre, 340 ft deep open pit, the largest truck-operated open pit metal mine east of the Rocky Mountains. A rich outlier of the deposit, the Leach orebody, was reached via a 48-inch diameter exploratory shaft but still remains unmined. When the mine closed in 1972 the reinforced concrete concentration mill was demolished, and the pit was allowed to flood. The landscape includes mountains of waste rock, and an extensive tailings impoundment.

Compared to many Appalachian sulfide mines, the Elizabeth Mine stands out as a particularly large mine and one that operated comparatively late in the twentieth century. Although it appears to be an anomalous resource, it is actually part of a continuum of mining. Mines at Ducktown, Tennessee; Ore Knob, North Carolina; the Blue Hill area in Maine; and other locations operated as late as the 1970s and 1980s. At that time, plate tectonics was revolutionizing ore deposition theory and the Appalachians were the scene of renewed prospecting for metals. Not surprisingly, new ore deposits were indeed located, and several large copper, molybdenum, and zinc-bearing sulfide deposits in Maine remain unmined. One of the most outstanding examples was found near Bald Mountain in northern Maine in 1977. This massive polymetallic sulfide orebody contains a copper-zinc-lead deposit similar in scale to the Ducktown mines. The weathered gossan cap has been calculated to contain 1.4 million tons of gold and silver ore. Because of environmental issues associated with bringing this orebody into production, it remains undeveloped. Across the Canadian border in New Brunswick, where the political climate is more encouraging of mining, some of the largest polymetallic sulfide ore deposits in the world have been discovered and developed there during the last half of the twentieth century.

The Elizabeth Mine is also not alone in being the subject of environmental issues and proposed cleanup activities. The Callahan copper mine on Cape Rosier, Maine, and the Black Hawk zinc mine at Blue Hill, Maine, are both being assessed under the EPA's Hazard Ranking Score process for possible addition to the EPA's National Priorities List. Many of New England's other historic Appalachian sulfide mine sites are sources of acid mine drainage and may warrant environmental study.

3.5 Extractive Industry in Vermont

Vermont has a rich heritage of extractive industry, including building stone, industrial minerals and metallic ores. Barre is a world-famous center for high-quality granite for monuments and sculptural work. Danby, Proctor and Rutland are centers for marble quarrying and finishing. Colored roofing and architectural slate is quarried in a belt from Pawlet to West Castelton. All of these districts include historic and active quarries and associated landscapes. Vermont's ophiolite rocks are an important source of industrial minerals, and include talc mining operations in Chester, verde antique "marble" quarries in Roxbury, and the massive asbestos mining complex on Belvidere Mountain in Eden Mills. Vermont's iron ore deposits fed numerous nineteenth-century blast furnaces in the southwestern part of the state, and gold-bearing slates were mined in Bridgewater and Plymouth. The other important metal that was mined in Vermont was copper, which was extracted from three major deposits in the Orange County Copper belt.

3.6 Mines of the Orange County Copper Belt

3.6.1 Elizabeth Mine, South Strafford

The Elizabeth Mine (VT-OR-28) operated almost continuously from 1809 to 1958 with some minor suspensions of activity (Figure 3.2). Of the three Vermont Copper Belt mines, it produced the highest tonnage of copper, and left the largest and most complex mining landscape. Mining began in 1809 for the production of copperas, or iron sulfate, an important industrial chemical. This operation eventually became a major domestic source of copperas until it closed in the early 1880s. Copper was smelted beginning about 1830 and in eight brief subsequent campaigns until 1919. The mine was revived for World War II and closed in 1958.

The Elizabeth Mine is associated with a number of significant political, commercial, and scientific figures. President James Monroe visited the Elizabeth Mine in 1817 as part of a goodwill tour of area industries affected by changing trade regulations. Early smelting activities were overseen by Isaac Tyson, Jr., a Baltimore, Maryland-based chromium chemical and copper mining figure. During the early twentieth century, mine redevelopment and smelting experiments were undertaken by August Heckscher, general manager of the New Jersey Zinc Company, a major American zinc mining and smelting concern. The mine was the scene of several important firsts in American copper metallurgy, including successful mineside smelting, large-scale smelting of sulfide ores, smelting with hot blast and anthracite, and successful use of chromite refractories.

The Elizabeth Mine produced an estimated 10,500,000 lbs. of copper before its World War II revival in 1943. After its revival during World War II it briefly became one of the 20 most productive copper mines in the U.S. and was the largest and most productive copper mine in New England. In 1953, the Elizabeth Mine was the nineteenth highest producing copper mine in the U.S. During the 15-year life span of the mine it yielded 90,000,000 lbs. of copper, and probably had a total lifetime output of more than 100,000,000 lbs. It ultimately outstripped its nineteenth-century counterpart, the Ely Mine at Vershire. When it closed, the Elizabeth Mine extended 11,000 ft horizontally and had about 5 miles of underground workings. The mine site, with its unique copperas works remains and massive mill tailings piles constitute a dramatic, highly unusual industrial landscape for New England. This landscape includes the only intact cluster of historic hard rock metal mine plant buildings in New England, among them a flotation mill that is an exceptional historic mining resource for the Eastern U.S.

3.6.2 Ely Mine, Vershire

The Ely Mine (VT-OR-14) was discovered after the deposit at South Strafford (Figure 3.3). The Ely Mine was active between the mid-1850s and about 1905, and its main contribution to U.S. copper mining occurred during the 1870s and 1880s. The Ely Mine included an 1867 smelting plant that expanded to become a massive mid-nineteenth-century non-ferrous metallurgical works, more than 700 ft long with 24 smelting furnaces. During the second half of the nineteenth century, the Ely Mine outstripped copper production at the Elizabeth Mine. The Ely was among the top ten producing U.S. copper mines between 1866 and 1881. It was the third largest-producing U.S. copper mine in 1873 and 1875, and ranked fourth through ninth in the rest of that decade. The mines overall production stands somewhere between 30 and 40 million lbs. of copper. The Ely Mine was significant as a mining boomtown in Vermont, included a substantial workers village and influenced the local economy. It was the scene of labor unrest that resulted in the Ely War. The Ely Mine was the only copper mine in Vermont where all technological aspects of refined copper production, from mining of raw ore to smelting of refined pig copper, were successfully integrated on a large scale.

3.6.3 Pike Hill Mines, Corinth

The orebody at the Pike Hill Mines (VT-OR-27) in Corinth was discovered after the deposits in South Strafford and Vershire (Figure 3.4). Pike Hill was the scene of intermittent copper mining from 1846 to 1919. Although the Pike Hill mines operated sporadically and were overshadowed by the Ely Mine and the Elizabeth Mine, they contributed an estimated 1/17th of the copper produced in the Orange County Copper

Belt. There was no smelting at Pike Hill; ore mined there was taken to Ely to be refined. One significant technological achievement for the Vermont Copper Belt was magnetic separation of the pyrrhotite from the milled ore at the Union Mine. This process, which failed at the Elizabeth Mine, was used successfully at Pike Hill in 1906 and 1907. The total copper production of the Pike Hill mines is estimated at 8,600,000 lbs.

3.6.4 Vermont Copper Production

Accurate estimation of Vermont's total copper output is difficult because of the lack of consistent records, particularly prior to the establishment of the United States Geological Survey in 1879 and associated agencies such as the U.S. Bureau of Mines. Early production figures are subject to interpretation because of unknowns including the richness of the ore, the efficiency of beneficiation, smelting and refining, processes, purity of shipped product and other factors. Based on conservative analysis of existing records it appears certain that Vermont was the second-largest copper-producing state for at least part of the 1870s. The major producers in order of production during the 1860s and 1870s were Michigan, Vermont and Tennessee. Vermont was far behind Michigan, which produced more than 60 percent of domestic copper from 1854 to 1882. The 1880, census placed Vermont, with 2,647,894 lbs. of copper, in third place behind Michigan's 40,389,212 lbs., and Arizona's 3,183,750 lbs. By 1882, the western mines began to pull ahead, and Vermont ceased to be a major contributor to U.S. copper production. Figures for production between 1943 and 1958 are more accurate. In 1953, the Elizabeth Mine was the nineteenth highest producing copper mine in the U.S. Between 1946 through 1956 it was among the top 25 producers and was twentieth in five of those years. In 1950, there were 300 copper mines in the country. The top five produced 67 percent of U.S. copper and the top ten produced 85 percent. Total copper output for the Orange County Copper mines between 1793 and 1958 has been estimated at about 145 million lbs., with about 100 million from the Elizabeth Mine, about 35 million lbs. from Ely and under 10 million from Pike Hill (Abbott *GMC* 1964: 144, 336-338, 444-448; Howard 1969).

In addition to the three major Orange County copper mines, sulfide copper ore was found and mined in minor quantities in Berkshire, Concord, Newport, Norwich, Plymouth, Waterbury, and other Vermont towns during the nineteenth century. Perhaps the most notable Vermont sulfide mine other than the Orange County mines was the iron pyrite mine it Cuttingsville in Shrewsbury. Located at the Cuttingsville railroad trestle, this mine was briefly worked for copperas during the 1830s.

3.7 Appalachian Sulfide Orebodies, Industrial Patterns and Landscapes

Mining involves the physical concentration of capital, manpower, transportation and technology in ways that profoundly influence the landscape. Mining landscapes are complex places resulting from overlapping layers of historic activity. Although many extractive industries share basic similarities, they also incorporate many differences resulting from their location; climate; surrounding topography; proximity to labor, water and transportation; period of operation; geology; commodity; ore type;

composition and richness and other factors. These factors dictate the logistics associated with removing the material from the bedrock and the technology used to prepare it for market. These methods in turn result in characteristic landscape features. The historic resources at a mine site are not just limited to standing structures; they encompass the full range of excavations, waste materials, transportation routes, and other aspects of mining operations. The major areas identified as sources of contamination and targeted for cleanup activities at Elizabeth Mine possess important values including historical significance, archaeological potential, and visual landscape value, and are the tangible reflection of technological choices based on many specific factors.

The chemistry, shape and arrangement of Appalachian sulfide orebodies generally resulted in similar patterns of mine development and similar landscapes. The mode of deposition and emplacement of Appalachian sulfide orebodies dictates that they are often exposed at the surface in a linear configuration. Usually the orebody is capped with a gossan, a layer of decomposed ore that has been leached of its sulfur and copper, leaving iron oxides such as hematite or limonite. This gossan was often the first indication of a sulfide ore deposit and was usually mined in open surface pits for its iron or copper content until the next level was reached. With depth the iron-rich gossan usually petered out and graded into a supergene ore zone of highly enriched copper sulfides including chalcocite. This zone was typically exploited for its high-grade copper ores that were relatively easy to smelt profitably until the next zone was reached. Mining these deposits involved shallow underground workings that generated moderate amounts of waste rock. Below the enriched zone usually lay the unoxidized, unenriched original sulfide orebody, which contained lesser amounts of copper and other metals in disseminated grains within the pyrite or pyrrhotite, making it difficult to extract profitably. Mining these deeper deposits required erection of tunnels and shafts and generated larger quantities of waste rock. Smelting this more refractory ore required new technology, multiple, energy-intensive steps, and left heaps of waste slag. About 1900, the advent of industrial electrification and new mass-production technologies were allowing profitable extraction of ores of lower and lower grade. These new processes yielded large quantities of mill tailings, finely ground waste materials that were deposited at the mine site. The changing nature of Appalachian sulfide orebodies with depth and the changing technology used to mine and refine them resulted in the evolution of different landscapes that lie around and on top of one another. Reconstructing that history and mapping the evolution of the resulting landscape can be extremely challenging for the mining historian, and is an important part of evaluating historically significant resources and locating sources of contamination.

Many Appalachian sulfide mines leave particularly degraded and dramatic landscapes because of the release of sulfur in the form of sulfur dioxide from smelter gases, and sulfuric acid from decomposing ore and open mine workings. The high acid content in the air and water result in a landscape that is often bare of vegetation, subject to pronounced erosion, and brightly colored. Although these aftereffects can be considered environmentally undesirable, they constitute an important part of the historical record of the evolution of mining activity. These landscapes are valuable for their potential to hold archaeological information, and they are also valuable purely as landscapes. They incorporate unfamiliar and unusual formal elements of scale, geometry, color, and texture that evoke powerful responses and have potential for interpreting ecological and environmental history.

4.0 History, Landscape and Resources of Elizabeth Mine

This chapter provides a detailed history of the Elizabeth Mine (VT-OR-28) landscape organized chronologically by mining operations, and provides preliminary assessment of the historic resources that exist from those periods as they appear today.

4.1 Pre-Mining Period: Eighteenth Century-1809

Strafford, Vermont, is located in Orange County, approximately 15 miles north of White River Junction and about 9 miles west of the Connecticut River. Strafford was chartered by Benning Wentworth, Royal Governor of New Hampshire, on August 12, 1761 to a group of men from Hebron, CT, who were granted the 36-square-mile township in roughly 70 undivided shares. At first, disputes between the colonial provinces of New York and New Hampshire made the validity of charters in what is now Vermont uncertain and the first settlers arrived in early 1768. A 1771 New York census counted nine families in Strafford, most of them living in the eastern part of the town. Adjacent Thetford was chartered on the same day and was settled earlier than Strafford, likely because of its proximity to the Connecticut River, which was the major north-south trade route of the period. Strafford remained a frontier town through the Revolutionary War and settlement did not begin to increase until Vermont was admitted into the Union in 1791. Census results for Strafford show that there were 845 residents in 1791, 1,643 in 1800, and 1,805 in 1810. Peak population for Strafford was attained in 1820 when there were 1,971 residents (Smith 2001).

The main economic activity in Strafford during the late eighteenth century was subsistence farming with limited local trade. A scattering of sawmills, gristmills, tanneries, fulling mills, and stores supplied local needs. Strafford was essentially self-sustaining, and commercial trade with Boston was limited. Potash made from wood ashes resulting from land clearing was an early valuable local export (Smith 2001).

The weathered iron oxide outcrop of the Elizabeth Mine sulfide orebody was discovered in 1793, allegedly by two men who were tapping sugar maples on the east slope of what was then called Prospect Hill, and discovered discolored water draining from the deposit. Regardless of the mode of discovery, the unusual phenomena associated with this geochemical anomaly incited local curiosity before its specific value was understood. Deeds associated with the land on which the ore outcropped from the late 1790s contain references to iron ore mining rights. In 1798, Asahel Chamberlain sold a parcel of land to Jacob Stevens, but reserved the right to mine the ore for himself. This land was where the Vermont Mineral Factory Company set up a copperas works about 10 years later. The identification with iron was typically associated with the discovery of Appalachian sulfide orebodies, as the gossan or weathered cap of the ore consisted of limonite, an iron oxide leached of metals (such as copper, zinc and lead) and sulfur. The primary constituent of the South Strafford orebody is pyrrhotite, an unoxidized iron-sulfur compound that lay below the gossan. The belief that this material could be smelted for iron persisted until 1809, when a misguided attempt to smelt this unsuitable ore in the Franconia, NH, iron furnace caused it to shut down (Abbott *GMC* 1964:2-12). Mining work on the outcrop at this time likely consisted of open-cut excavation of the soft oxidized layer in the vicinity of the north end of the North Open Cut.

4.1.1 Known Resources

Only two standing structures are known to date from pre-mining activity at the Elizabeth Mine Site and both are the earliest components of occupied dwellings with later additions. The much-altered house at 170 Mine Road, said to date from 1793, was used as an infirmary and carpenter shop during the World War II era operations, and includes an ell dating from about 1942 (Smith 2001). The earliest part of Buena Vista, a mid-nineteenth-century house further north on Mine Road, is a back kitchen said to date to 1795 (Hartgen 2000:21). Mine Road, formerly the Norwich Strafford Road, appears on official Vermont maps made by Vermont Surveyor General James Whitelaw in 1796 and 1810.

4.1.2 Expected Resources

The lands that currently comprise the Elizabeth Mine site were formally farmlands and woodlands owned by various local residents. These lands were subsequently used by the mining companies by agreement with the landowners. A review of historic maps is inconclusive as to whether farm-related structures such as dwellings, outbuildings, sheds, wells, privies, and stone walls existed within the site area. However, it would be highly unlikely that any such resources would have survived impacts from mining activities that began during the first decade of the nineteenth century.

4.2 Copperas and Copper Manufacturing: 1809-1880s

4.2.1 Copperas Production on East Slope of Copperas Hill 1809-1880s

4.2.1.1 History

After the failure to produce iron from the South Strafford ore at Franconia, attention shifted from iron to copperas production, and Prospect Hill became known as Copperas Hill. Copperas is a fourteenth-century term for crystalline green hydrous iron sulfate, an important early industrial chemical compound derived from processing iron sulfide ores. Copperas had a multitude of uses over the centuries. It was used to blacken and color leather, as a disinfectant and sheep dip, as an astringent medicine, and as a drier in ground pigment manufacture. Its properties as a wood preservative have resulted in preservation of timber and plank structures in the copperas production area at the mine. It was used in the manufacture of Prussian blue, indigo dye, and could be processed to make paint and polishing powder. It was used for water and manufactured gas purification. It was used for production of sulfuric acid and in associated metalworking, including precipitation of dissolved gold. It was used as a dye mordant, which fixes dyes by combining with them and turning them into insoluble compounds. It added color permanence to black and brown wool dyes and fabric printing inks, and was widely used in the dyeing and tanning industry (Agricola 1556:572; Biringuccio 1540:97; Brady 1947:272-273; Diderot 1751:Plate 151; Wagner 1872:32). The copperas from South Strafford was used primarily by the woolen, cotton, dyeing and hatmaking industries (Smith *Copperas* 2001:11).

Copperas production was a simple process that is well documented in sixteenth and seventeenth-century accounts, and changed little until the late nineteenth century. The raw material was iron sulfide, or pyrite-bearing soil or metallic ores that were gathered by excavation. The process made use of gravity, and was often located on a hillside. Typically, the pyritic material was piled into mounds, or beds, where it was left exposed to the elements to oxidize, for months or even years. Later, the material was roasted to promote breakage of the ore and release of the sulfur. The beds were usually on an elevated and cleared surface that was lined with clay to make it impervious. After a period of oxidation the beds would release a liquor of ferrous sulfate and sulfuric acid when water was allowed to flow through them. The resulting liquor flowed in plank-lined channels to a large holding cistern. The liquid was pumped into lead-lined boilers fueled with coal or wood and boiled, sometimes with scrap iron. When the liquid was sufficiently concentrated, it was poured off into flat, shallow crystallizing pans where it crystallized on the inside surfaces and sometime on tree branches added to the tank. The leftover liquor was re-boiled. The copperas crystals were scraped off, melted into molds, and packaged for shipment and sale (Agricola 1556:576-578; Biringuccio 1540:95-97; Diderot 1751:Plate 151; Wagner 1872:32).

Copperas was an important chemical in seventeenth-century colonial America. Like iron and other products, its domestic manufacture was discouraged by the British, and the Revolutionary War created opportunities for its production. Late eighteenth-century copperas works were set up in Brookfield and Hubbardston, Massachusetts, areas known for strongly pyritic bedrock (Smith *Copperas* 2001:6-7).

The earliest people to dig the South Strafford ore were local men, but the deposit was not worked profitably until the arrival of the financial and technical aid of outside experts. A September 30, 1809 deed notes that the South Strafford deposit was being mined and copperas was being made by that date. Between 1809 and 1812 several companies were formed to mine and produce copperas in Strafford and the adjacent towns of Thetford, Norwich, Hartford, and Sharon. Starting in January 1809, a series of outside figures, several from New Hampshire, began to buy up the land around the South Strafford ore outcrop. On October 31, 1809, this group officially incorporated as the Vermont Mineral Factory Company, and continued to acquire additional land around the deposit. Key figures in the Vermont Mineral Factory Company were Colonel Amos Binney, a Boston merchant, and his son, Amos Binney Jr. The senior Binney figured prominently in the early Vermont copperas industry. In 1826, the junior Binney became a partner in the copperas business, and later pursued the first attempts at extracting copper form the ore (Abbott *GMC* 1964:7-11).

The initial operations of the Vermont Mineral Factory Companys South Strafford copperas works took place during a period of unfavorable economic conditions. Until 1807, all copperas was imported from Europe. The 1807, Embargo Act restricted trade with the belligerents in the Napoleonic Wars. Restrictions on imports of chemicals and minerals affected Vermont industries, and served as an inducement for the domestic production of compounds including copperas, the production of which was so important that copperas workers were exempted from military duty. In 1810, the first full year of production, the Vermont Mineral Factory Company produced 8,960 lbs. of copperas valued at $1,200. Before the War of 1812, copperas sold for 4 or 5 cents per lb. In 1812, Josiah Quincy petitioned Congress on behalf of the Vermont Mineral Factory Company to place a duty on foreign copperas. The company was confident that it could supply the country's entire demand and wanted a protective tariff in place to protect its interests. During the war the price of copperas rose from 12 to 16 cents per lb. and the operation became more profitable. After the War of 1812, the English flooded the copperas market and the Vermont Mineral Factory Company copperas works were unprofitable during the depression that lasted until 1822. Congress did establish a duty of 1 dollar per 100 lbs. on imported copperas in 1816, but it proved ineffective (Abbott *GMC* 1964:11-13).

In 1817 President James Monroe undertook a tour of the United States that included Norwich as the northernmost stop in eastern Vermont. Amos Binney had previously served as agent of the U.S. Navy Yard in Boston, where he had met Monroe. Binney encouraged Monroe, who had a deep interest in domestic manufacturing, to change his Vermont tour itinerary to include a visit to the Vermont Mineral Factory Company at South Strafford. As a major manufacturer of copperas, Binney wanted to influence Monroe's future support of the industry. Finally, in 1824 Congress raised the copperas tariff from 1 cent to 2 cents per lb., and maintained tariffs to protect the industry. According to Binney, this 1824 tariff was the key to profitability for the domestic copperas industry, and allowed the Vermont Mineral Factory Company to become profitable and to develop into a major American supplier. Before 1823, production averaged 25 tons per year, but it increased to 800 tons in 1826 (Abbott *GMC* 1964: 12-15).

In 1828 Amos Binney, Jr., formed the Green Mountain Manufacturing Company to exploit another iron sulfide deposit at Cuttingsville in Shrewsbury for copperas production. Statistics for the period are not entirely consistent but give some idea of the magnitude of the operations. The Cuttingsville plant produced 200 tons of copperas in 1829, 400 tons in 1830, and 600 tons in 1831. The South Strafford works averaged 750 tons annually from 1824 to 1831, with production of 1,000 tons in the last year. According to Binney, the combined output accounted for 75 percent of United States production, with Ohio and several other states producing the balance (Abbott *GMC* 1964:17-18).

Until the early 1830s the South Strafford copperas works drew its raw material from an open pit, the North Open Cut, located near the top of Copperas Hill. Amos Binney began developing underground workings and in 1831 mining was also being conducted via the 313 ft Upper Adit (horizontal tunnel) driven into the orebody, and a 100 ft air shaft sunk to ventilate the workings. These workings were located roughly half way up the slope of Copperas Hill. This development gave access to new sources of pyrhhotite for copperas, and with it larger quantities of copper ore for the copper smelting efforts described below.

Copperas production through the 1830s and 1840s remained around 1,000 tons annually. The Shrewsbury operation was closed in 1837. In 1844 and 1849, production was reported at 1,600 tons, and an 1854 report listed production at 1,500 tons. The Connecticut & Passumpsic Rivers Railroad reached Pompanoosuc (Norwich) in 1848, greatly improving the transportation situation for the copperas works. Copperas was shipped to major cities including Baltimore, Boston, Charlestown, SC, Hartford, Richmond, and Troy, NY (Abbott *GMC* 1964:19, 35). Between 1842 and 1862 the tariff on foreign copperas was gradually lowered to 2 cent per lb., allowing foreign sources to make inroads and prices to drop. In November 1854 another tunnel, the Deep Adit, was begun at a point lower down the hill, roughly west of the sharp bend in the road below the copperas works at TP 3 (Abbott *GMC* 1964:272).

After the Civil War, in 1867, the mine was taken over by the New England Chemical Company, which operated two copperas plants and a paint works at the site. Soon the New England Chemical Company was taken over by the New England Chemical Manufacturing Company, which operated the copperas works during the 1870s under William H. Foster and Joseph W. Cleaveland. Around 1880, the copperas works employed 50 workers. In 1882, it was deeded to the Strafford Mining Company, but subsequently shut down because of competition from new sources of copperas. (Abbott *GMC* 1964:273-276). The manufacture of copperas from natural materials ended in the 1880s when large, inexpensive sources of iron sulfate became available as a byproduct of the burgeoning steel industry. Iron sulfate was extracted from waste sulfuric acid that was used to Apickle, or wash iron oxide scale from steel sheet and wire prior to galvanizing or finishing. The spent sulfuric acid was boiled with scrap iron and the resulting liquor was processed to yield large quantities of inexpensive byproduct iron sulfate (Day 1885:952).

4.2.1.2 Process

The owners of the South Strafford copperas works apparently expanded and improved their works several times. The scale of the works in terms of its landscape and factory buildings far exceeded any other manufacturing concerns in the area. The process generally followed the method described above, with some methods, notably ore roasting, employed to accelerate the ore decomposition process. An important general aspect of the arrangement of the works was the way that the steep hillside was used to promote the Acascading nature of this process, using gravity and water to move the materials (Smith *Copperas* 2001:13-14). The affairs of the copperas works were documented in several mid-nineteenth-century accounts. Not all of these include descriptions of the works themselves, but a few do provide information about the operations that can be used to interpret the location and arrangement of the various phases of the operation and the function of the various features on the hillside. The most detailed of those articles are quoted directly below.

The U.S. Census of Manufactures for 1810 notes that 20,000 tons of ore were blasted, twelve Ascaffolds were built and filled with the ore, yielding about 4 tons of copperas. This indicates that the ore was placed in heaps or beds confined by some sort of structure, presumably made of timber. These were apparently for leaching rather than roasting, as that process was not adopted until later. This is supported by an 1821 account by Dr. John Locke, who reported that originally the ore had been simply leached for its copperas content, and later was roasted to speed decomposition:

> For several years the manufacturers effected the decomposition in the following manner: the ore was broken into fragments of a foot or less in diameter, and heaped upon inclined scaffolds erected and floored with plank for the purpose. Thus exposed to the action of air and moisture, it very gradually decomposes at the surface. Thus from the same mass of ore a solution was obtained, year after year, either by the rains or by the application of water by other means. The solution was received from the inclined scaffolds in plank cisterns.

(This process was slow, had limited throughput, and may have resulted in diminishing returns. Soon, they added a roasting step, which accelerated the leaching process and allowed greater throughput of ore):

> For three or four years past [1817-1818] they have adopted a more expeditious method of decomposition, which was discovered in the first place by accident. They break the ore into much smaller fragments, three inches and less in diameter, and throw them into a convenient heap, taking care to leave air holes at the base so as to allow the air to pass freely through the heap. On applying water the decomposition commences, and so much heat is evolved as presently to raise the temperature of the heap... [so that] in the course of three or four weeks the whole becomes disintegrated and ready to fall into the state of powder. It then by lixiviation with water yields all its copperas at once; the process is performed in a plank cistern.
>
> The manufactory in which the processes of evaporation and crystalization are performed is placed on the declivity quite below the mine. This gives great facility to all the operations, allowing the various reservoirs to be so arranged one above another that the liquor may be transferred from one process to another merely by means of a trough.
>
> The bottoms of the evaporating vessels are of lead, and about ten feet square; the sides are of wood about three or four feet high. The bottom is supported by a number of parallel brick walls, placed at a small distance from each other. The avenues or arches between these walls communicate at one end with the arch in which the fire is placed, and at the other with the common flue.

> The ore is a sulphuret of iron with a small proportion of copper; and the solution, first obtained, is a sulphate of iron and copper with an excess of acid. During the process of evaporation a leaden vessel, having its sides perforated and containing fragments of old iron, is suspended in the liquor. The iron at the same time that it neutralizes the excess of acid decomposes the sulphate of copper and the copper is precipitated in the form of fine powder which the workmen call "copper mud"….
>
> After the liquor has been sufficiently evaporated it is drawn off into cisterns to crystalize. Branches of trees are put into them as a nucleus for the crystals. When the crystalization has proceeded as far as it will go, the remaining fluid is drawn off and returned to the evaporating vessels. The cistern remains lined several inches in thickness with crystals, like a geode. The branches have a fine crop of foliage and fruit composed of beautiful green crystals. The crystals are very large and perfect, presenting numerous brilliant facets which are often several inches broad….
>
> An ingenious method has been contrived to catch the wash of the whole mine. There has been cut in the compact ore, quite across the lower edge of the mine, a channel, into which by its inclination the mine discharges the wash of every shower, together with the natural oozing from the hill above. A trough conveys the fluid from the channel to the boilers. To increase the effect of this natural brook of copperas, the ore has been broken into large fragments, and heaped along the upper side of the channel, there to undergo a slow decomposition precisely as it does upon the scaffolds mentioned above (Locke 1821:326-330).

In 1824, Zadock Thompson reported that:

In 1822, the works having been considerably enlarged. The building in which the manufacture is carried on is 180 feet long and 46 wide. The ore is beaten to pieces with hammers and thrown into heaps several rods in length, about 12 feet in width, and seven or eight in height. Here it is suffered to lie exposed to the action of the air and moisture until a spontaneous combustion takes place, and the whole heap is converted from the sulphuret to the sulphate of iron, which usually takes several weeks. After the process of burning is completed, the residue is removed to the leaches, where water is passed through it, which dissolves the copperas and leaves the earthy matter behind. The water is then conveyed to the boilers, which are made of lead, four in number, and weigh about 2500 pounds each. Here it is boiled and evaporated to [a] certain extent, and suffered partially to cool. It is then transferred to the crystalizers, where the copperas continues to crystalize, while cooling, and when the crystalization ceases, the water is again returned to the boilers, mixed with water from the leaches, and again evaporated (Thompson 1824:251-253).

In 1827, the following description of the works appeared in the *Columbian Centinel*:

> Upon the highest extremity of the hill is the *Magazine,* which is almost inaccessible, and such a distance from the other buildings, that in case of an explosion, no other injury would be occasioned; a few rods below this is a *Blacksmith's Shop,* in which a workman is constantly employed in making and repairing drills, and various other utensils; a few yards distant from this, is the *Upper Factory, so* called; northeast of this, is the brick boarding house, adjoining which is the *Counting House*; directly opposite this, is the lodging house of the workmen. Descending the hill still farther (about ten rods distant) is another *Factory,* which is 267 feet long, and 94 wide, including the packing apartment; the two factories contain ten leaden vats, the average size is 10 feet by 12, and 21 inches in depth. In the southern part of the works are several temporary buildings, erected for the preservation of the copperas (sulphate of iron).
>
> The ore, by the following process, is converted into copperas: First with the use of a drill, a perforation is made from 10 to 30 inches in depth, and by means of powder large portions are separated from the fodina, which are broken into small pieces and conveyed to a suitable spot, until a sufficient quantity is accumulated for a *heap,* which in the space of a few days will ignite spontaneously. In this condition it remains burning without cessation for about two months, which mostly consumes or expels the sulphur with which the pyritous rock is saturated. Sometimes the heaps are set on fire by the workmen to hasten process, and entirely pulverizes the integral heap. The surrounding objects wear a sterile and deleterious appearance, but the health of the workmen is completely preserved. From these disintegrated heaps the pyrites is thrown upon leaches, and the lye drawn into reservoirs, from thence into leaden vats. Lead is the only metal which endures the operation of the liquid. The lye is boiled in these vats until it arrives at a proper degree of strength, when it is drawn off into wooden vats, where it remains for crystalization, upon the sides, and the boughs of trees, which were formerly thrown into it to form crystals upon, but of late an improvement has been introduced a stick of wood, about 6 feet long and 2 inches in diameter, through which at proper distances holes are bored, and small sticks inserted about 18 inches in length and 3/4 of an inch in circumference, on which the crystals formed much larger and has occasioned the entire abandonment of the old method. The crystals are somewhat quadrangular, and in color a beautiful transparent green. From thirty to forty workmen are employed (anon., *Columbian Centinel* December 1, 1827:1).

In 1842, Zadock Thompson, in his *History of Vermont*, described the copperas works:

> Strafford Copperas Works. There are 2 factories, each about 267 ft. in length by 94 in width. These contain 8 vats made of lead, 10 ft. by 12 ft., 21 inches in depth and three fourths of an inch in thickness, used for boilers. Lead is the only metal that will endure the operation of the copperas liquor, and this requires constant repair . . . The process of making [copperas] is as follows. The ore is blasted from the bed by means of powder. It is then broken into pieces with sledges, and afterwards the miners sort and break it up still finer with hammers. It is then thrown into large

> heaps, where it ignites spontaneously, or fire is sometimes set to it to hasten the process. In this condition it generally burns for the space of two months; in that time the sulphur is converted into sulphuric acid, and unites itself with the iron, forming sulphate of iron, or copperas. These heaps of pyrites, being now thoroughly pulverized by fire, are carried to places where water, from a fountain on the summit of the hill, is made to run upon and leach this mass of crude sulphate of iron. The lye is now drawn off into large wooden reservoirs, and thence into the leaden vats as fast as wanted. In these vats the lye or liquor is boiled to a certain strength, tested by acidimeters, and then drained off into wooden vats, where it remains to crystalize. Branches of trees were formerly thrown in for the crystals to adhere to; but Mr. Reynolds, the present agent, has made an improvement. Pieces of joist 3 inches square, 6 ft. long, laid across the top of the vats, with holes bored, and round sticks 18 inches long by 3/4 of an inch in diameter, inserted at intervals of about 6 inches, are now used with great advantage. This makes a great saving of labor, although it has in some measure destroyed the fanciful shapes, which the crystals formerly assumed upon some favorite branch. The crystals are multiangular, and of a beautiful transparent green color. After crystalization takes place the liquor is drained off, and the copperas is shoveled into the packing rooms. When dry it is usually put into casks holding about half a ton each, but frequently into casks of every size (Thompson 1842:167-168).

In 1845, Charles B. Adams, Vermont State Geologist, made the following observations at the coppers works (See Figure 4.1):

> [At Strafford] not only the inexhaustible quantity and purity of the ore, but its situation also give unusual facilities for the manufacture of the copperas. The vein is worked to the open air - large blocks of ore being blasted out and the with sledges broken to the size of an egg. These fragments are then removed a little down hill and formed into an immense conical heap, in which air and moisture sustain a smothered combustion, which has been only commenced by wood fuel and which, if not checked by an excess of water, would be sufficient to drive off the sulphur, and to vitrify the mass. In this process, the water flows from a higher level to the top of the heap, and the only inconvenience attending the manufacture is the limited supply of water in dry weather. In this process, by the oxygen of the air, the sulphur is converted into sulphuric acid (oil of vitriol), and the iron into oxide of iron, which, combining together, constitute copperas. This, being soluble in water, is leached out by the stream of water, and the lye runs down into a vat, in which it is concentrated. It is then drawn down into other vats for crystallization. Stalactites of copperas are seen pendant from the troughs, and, with the exception of the green tinge, exactly resemble icicles - a singular spectacle in the heat of summer (Adams 1845:56).

In 1861, Edward Hitchcock, in his *Report on the Geology of Vermont,* reported:

> The process consists in first raising the ore from the bed, which is principally done with the help of gunpowder. The blocks of ore are then broken up into small pieces

> to facilitate the decomposition, by suffering the oxygen contained in water and the atmosphere to come more directly in contact with the material composing the ore. Large heaps of these pieces, called leaches, are made upon a tight plank bottom, or upon a sloping ledge of solid rock, where the liquor or lye that subsequently runs from them may be saved.
>
> In dry weather, a small stream of water is made to flow upon, and penetrate these leaches, in order to produce a spontaneous combustion, which in warm weather commences in a few days, and if properly managed will continue several weeks. When combustion is taking place, great care is requisite in order to have the work go on successfully, for if too much water is suffered to penetrate the leach or heap, the decomposition is checked by the reduction of temperature, and the lye or liquor issuing from it is too weak to be valuable; and if there is not water enough put on the leach, the decomposition is also arrested by the absence of the oxygen found in the water, which is necessary to convert the sulphurous acid into the sulphuric, that sulphate of iron or copperas may be produced.
>
> The liquor that runs from the leaches is collected in reservoirs, from which it can be taken at pleasure. Below the reservoirs upon the hillside, buildings are erected, called evaporators, to which the liquor is conducted in troughs from the reservoirs in small streams, that are divided and subdivided by means of perforated troughs, brush, etc. Several tiers of brush are arranged in the building, through which the liquor is made to pass to facilitate the process of evaporation. In dry, windy weather, the evaporation is oftentimes so rapid that the brush and other substances with which the liquor comes in contact during the latter part of its journey, often have an incrustation of copperas formed upon them; but upon the return of rainy weather, the humid atmosphere checks the evaporation, and the crust of copperas is dissolved and passes with the liquor into reservoirs prepared to receive it.
>
> The liquor which is now very strongly impregnated with copperas, is conducted into leaden boilers, where heat is applied and the liquor reduced to a strength indicated by the acidimeter to be right for the production of copperas. The liquor is then placed in vats of lead or of brick and water cement, called crystallizers, and after remaining from eight to ten days, a crust of copperas is formed upon the bottom and sides of the vats, composed of nicely formed crystals. The water remaining in the crystallizers is then pumped back into the boilers, the crust of copperas removed, and, after being sufficiently drained, it is packed in casks ready for market (Hitchcock 1861:829-832).

The last detailed account of the copperas works appeared in the 1871 *Vermont Historical Gazeteer*. The works as described are probably close in configuration to the works as depicted on the 1874 Vermont Copperas Company map (Figure 4.2). This is perhaps the most detailed description, and contains information about the preparation of the roast bed and heap leaching ground surface:

The copperas works of the New England Chemical Co. may be briefly described to consist of a prepared bed or bottom upon which the ore is burnt and leached. This bed is upon the hillside just below the vein. It is prepared by simply scraping the earth clean from the ledge and stopping all the seams and fissures in the ledge with moistened clay. The bed so prepared is nearly an acre in extent and is called the leaching ground. On the lower side of the leaching ground a trench has been dug in the ledge and this trench is connected, by means of spouts, with four large reservoirs near by, holding 20 hogsheads each. Still further below are two high sheds, open at the sides, with loose floors and each floor filled with brushwood these are called Evaporators. Upon a level spot below are the two factories of the Company, each 110 feet in length by 25 feet in width. These factories contain the evaporating pans, two pans in each factory, each pan being 26 feet long by 10 feet wide, and 16 inches deep. They are made of very heavy lead 1/4 inch in thickness. Lead is the only cheap metal which is not quickly destroyed by the action of the copperas. Beneath the evaporating pans run a series of flues, commencing at the fire arches at one end of the pans and terminating in the stack at the other end. There are also two lead coolers and 20 cemented brick crystalizers in each factory, each crystallizer being 14 feet by 7 feet by 18 inches deep. Directly beneath the crystalizers is the packing room.

The process of manufacturing copperas is as follows:

The ore is blasted from the vein, broken up so that it can be easily handled, wheeled to the sheds by means of handcars where it is again broken into pieces the size of large apples; it is then shoveled into cars again and run out upon the leaching ground and placed in large heaps containing from 500 to 3000 tons each. A quantity of wood is placed under one side of the heap and set on fire. The heat of the burning wood raises the temperature of the ore, so that the sulphur is ignited, and by degrees the whole mass is heated, the interior portions often red-hot. Great care is exercised in burning, to prevent the heap from being overheated, as in that case the iron of the ore would be melted and run into large solid masses and the sulphur would be driven into the atmosphere as sulphurous acid gas. To prevent this, a stream of water is applied at frequent intervals to cool the burning ore, but not enough to put out the fire. In this way a large heap will burn during four months, and frequently after it has been thoroughly drenched with water and has shown no signs of fire for six months, it will be ignited by spontaneous combustion and burn again with great vigor, when it is again treated with water as before. The object of the burning is simply to oxidize and decompose the ore. The oxygen from the water and the air striking upon the heated ore forms a weak sulphuric acid, which acts upon the iron of the ore and thus sulphate of iron in its crude state is formed in the heaps. A heap, if properly burned, will in a year's time become thoroughly decomposed and ready for leaching.

The process of leaching and evaporating has for its sole object the conversion of the crude copperas, as it exists in the heaps, into the beautiful green crystals, as found in the packing room, when ready for market. To accomplish this, a small stream of water is run upon the heaps and so directed as slowly to soak into and saturate the whole mass of decomposed ore. When the ore can contain no more moisture, the water settles to the bottom of the heap, falls upon the prepared surface, runs into the trench below and is conducted to the reservoirs near by. It is now called copperas liquor and its specific gravity or strength is measured by hydrometers manufactured for this purpose. The liquor generally shows a density of from 10° to 20°, water being 0, and this density, as ascertained by the hydrometer, shows its strength or goodness. This liquor is crude sulphate of iron in a liquid state. After being allowed to stand and settle in the reservoirs two or three days, it is conveyed in spouts to the top of the evaporators, where it is run over a surface so arranged that it is sprinkled in drops through the brush of the successive stories and by this expedient a portion of the water is taken out by the influence of the sun and air. On a clear summer's day, the liquor will be increased from 3° to 5° in strength, in passing through these two sheds. From the lower evaporator the liquor passes directly to the factories where it is received in large reservoirs, whence it is drawn into the evaporating pans as needed. In these pans it is boiled down till it reaches the strength of 35° when it is drawn into the lead coolers and there allowed to stand two or three hours in order to settle any impurities which may still remain. When quite cool it is passed into the cemented crystalizers. Here it usually remains a week, during which time the process of crystalization takes place. The liquor of crystalization is then drained off and pumped into the evaporating pans, where it mingles with the fresh liquor. This process is repeated with the liquor of crystalization ad infinitum.

The crystals of copperas are deposited in a thick, heavy coating on the sides and bottoms of the crystalizers; this coating is frequently 5 inches in thickness. The appearance of the interior of the crystalizers, after the liquor has been drained off and before the crystals have been disturbed, is extremely beautiful. The crystals are of a brilliant, transparent, emerald green, assuming various forms and sizes - some are spear-like and sharp as needles, while others assume the shape of German letters and fanciful devices. The figures formed on the bottom of the crystalizers by the grouping and arrangement of the crystals afford a beautiful and interesting study. One of the more common forms observed is that of perfectly defined rosettes of various sizes, raised an inch or two above the surrounding level. Sometimes these bottoms are broken up into regular successions of little rippling waves, as when a lake is agitated by a gentle breeze. The copperas is broken from the sides and bottoms of the crystalizers and shoveled down into the packing-room below. It is packed in strong casks holding 2000 lbs. and 500 lbs. each In this state it is shipped to Pompanoosuc Station, on the Connecticut and Passumpsic River Rail Road 10 miles from Copperas Hill, whence the larger portion is sent to Boston and there sold (Duncan 1871:1085-1088).

An undated photograph of the copperas works area probably depicts the operation at about this time (Figure 4.3).

4.2.2 Historical Significance

The bulk of what is today called Tailings Pile 3 (TP 3) resulted from the copperas production. This area is highly significant for several reasons. It was one of the largest, most successful and longest-lived nineteenth-century sulfide ore copperas works in America. It is a rare surviving site of copperas production in America and has the potential to reveal important archaeological information about the copperas manufacturing process, information that can be contrasted with and enriched by examination of general copperas production literature and site-specific written descriptions. It is an unusual surviving example of an archaeological site associated with the early nineteenth-century American chemical industry, and with the economic and political events associated with the encouragement of domestic industry and improvements. It is also an example of a site that was actually visited by President James Monroe as part of those events. It is not known how many sites still exist that can share that claim, but the site appears to be particularly rare in that context. It is unique to the Elizabeth Mine site, and no evidence of copperas production exists at the Ely or Pike Hill mines. It is not known what remains exist at the Cuttingsville copperas works site, or at copperas production sites elsewhere in the United States.

4.2.3 Known and Expected Resources

4.2.3.1 Current Landscape and Visible Features

The Copperas Hill sulfide ore mining and copperas processing activity was roughly confined to an area including the North Open Cut and the hillside below it (TP 3) to the vicinity of the present sharp bend in the road to Thetford. Today this area is one of the two largest and most dramatic historic landscapes at the Elizabeth Mine. The North Open Cut at the top of the hill is a long, narrow, deep, north-south oriented, man-made cut in the rock. It is almost 1,000 ft long and its north headwall contains several large open excavations. The slope below it is divided into two areas by a dirt road. The entire slope is almost entirely devoid of vegetation with the exception of the occasional acid-tolerant birch, poplar or pine. The area above the road is characterized by uneven, shallow heaps of yellow waste eroded by gullies and peppered with lumps of brownish-purple pyrrhotite ore. Stepped arrangements of timber and segments of dry-laid fieldstone walls emerge from the soil in places.

The dirt road that bisects the area is built on fill in places that contains mine drill core fragments and other mine-related waste. The area below the road is less steep, and is roughly triangular, funneling down toward the road to Thetford. The south section of this area consists of an uneven landscape of rounded mounds of vermilion and purplish-black waste with scattered patches of burnt and fused ore, possibly roast beds for the copperas works. Some of these mounds are ringed by remains of vertical wooden posts. Red brick is scattered around this area. The north section of the lower area is dominated by a large conical pile of yellow earth. A low fieldstone foundation is located immediately north of this pile. The area below, to the east includes tiers of partially buried structures built of heavy timber and thick plank, and stone foundations incorporating heavy iron brackets. This appears to be the remains of one of the copperas factory buildings. Copperas Brook emerges from the waste piles at this point and has carved a channel though the building ruins. Several dozen feet to the south, in a wooded area, is a large rectangular fieldstone foundation that incorporates heavy iron brackets and castings, possibly a second copperas factory. There are no signs of the two adits or the shaft, which appear to be collapsed and filled with mine waste.

Most of the early copperas ore explorations in the vicinity of Copperas Hill resulted in small prospect pits and abortive mining ventures. One additional area that should be mentioned, however, is the South Mine, located at the southernmost exposure of the ore, several hundred feet south of the South Open Cut. This outcrop was worked by the Vermont Copperas Company, and may also have been worked by their predecessor, the Vermont Mineral Factory Company. It may actually have been the site of the earliest attempts to mine the South Strafford orebody, but it appears to be a small outlier of the main deposit and was not mined extensively. The extent of belowground physical evidence of mining activity at this site is unknown.

The only standing buildings associated with this period of operation are the Copper Castle possibly built ca. 1840-1855, and Buena Vista, which dates to 1859, and includes several barns and outbuildings. These buildings are discussed in the previous historical report (Hartgen 2000:20-22).

4.2.3.2 Expected Resources

For this period of activity and for those that follow below, expected resources include but are not limited to those features or elements that are known to have existed based on the documentary record and may be buried or have yet to be located or identified at the site. Based on the known site history, and the 1874 Vermont Copperas Company map, those resources include the caved upper and lower adits and the shaft, roasting and heap leaching structures, and foundations of two copperas crystallizing factories, three evaporator buildings, the cob shed, blacksmith’s shop, agent’s house, office, several worker houses, powder magazine and barns. Additional expected resources include the infrastructure used to convey the copperas liquor between the phases of the operation, including prepared bedrock surfaces and wood or metal conduits.

4.2.4 Physical Integrity

Erosion from the headwaters that form Copperas Brook has slowly changed the surface of TP 3, exposing historic timber and masonry features apparently associated with the copperas production process both above and below the road that cuts through the tailings pile. The brook was recently channeled in the area immediately west of the bend where it crosses Mine Road directly east of TP 3. In the 1950s, a mining haul road was built across the face of Copperas Hill, cutting through the copperas production area. This road was built and/or repaired with fill brought in from elsewhere on-site as the road embankment is full of mine-related debris. Otherwise the impact of later mining activity on this hillside is unknown.

4.2.5 Research Value and Interpretive Potential

The copperas works area is assigned a high research value because of the information it contains about the design, layout, process and technology of nineteenth-century copperas manufacturing. Historical literature on copperas production in general exists, and several short descriptions of this particular facility were written during its period of operation. However, no detailed drawings or site plans showing the specific location and arrangement of roast beds, leaching piles, plant interiors or materials handling infrastructure are known to exist. Therefore, further historic and archaeological investigation of the copperas works area is expected to yield important information about the specific nature of copperas production at Elizabeth Mine.

The copperas area is a dramatic, colorful landscape and would be valuable for general interpretation of the impact of industrial activity on the land. Assessing the potential of the area to interpret copperas production without site mapping and further archaeological and literature research is difficult as the existing landscape does not clearly show how the site functioned. The mechanical aspects of copperas production would be easier to interpret through the physical layout of the site itself rather than simply through an explanation of the chemical reactions involved.

4.3 Copper Smelting at Furnace Flat South Bank ca. 1830-1839

The Vermont Mineral Factory Company did not confine itself entirely to copperas production. As early as 1821, it became apparent that the unoxidized pyrhhotite contained chalcopyrite, a copper-iron sulfide. Some copper was actually precipitated from the copperas solution by precipitation onto scrap iron, producing copper mud. Amos Binney, Jr., decided to pursue copper extraction on a larger scale, and undertook the underground mining activity on the east slope of Copperas Hill described above to open up more copper ore. By 1830 Binney had acquired additional copper ore prospects in Strafford and parcels of land on the Ompompanoosuc River approximately 1 mile north of the mine with rights to build a dam and raceway for a smelting plant. This area, now known as Furnace Flat, is located roughly 2 miles east of the village of South Strafford on Route 132, on the Ompompanoosuc River. Development in this area also included construction of a road from the mine to the south side of the river, which can still be followed (Abbott *GMC* 1964:16-17).

The pursuit of copper prompted the Vermont Mineral Factory Company to seek outside technical help. The first to arrive was Daniel Long of Harford, Maryland, in 1831 or early 1832. The source of Longs experience is unknown, but he may have worked for Isaac Tyson previously in Maryland. Under Long, it appears that two smelting furnaces were built on a bend on the south bank of the Ompompanoosuc River, 1 mile north of the mine. It is unlikely that much copper was produced before May 1833, when Isaac Tyson, Jr., took over as superintendent of the copper smelting and copperas works. Tyson had previously purchased copper prospects from Amos Binney and was involved in other Vermont mineral exploits. In 1833, Tyson, Binney, and members of the

Reynolds family incorporated the Boston Copper Mining Company to work both the South Strafford and Vershire deposits (Abbott *GMC* 1964:17, 20).

Isaac Tyson, Jr. (1792-1861) was a pioneering nineteenth-century American industrialist in the areas of mining engineering, industrial chemistry and metallurgy. He established and dominated the American chromium chemical industry and established the world-renowned Baltimore Chrome Works, which supplied world markets for chrome for pigments for 140 years. He developed numerous chromite, copper and other mines in the mid-Atlantic states. Tyson was an instrumental figure in the development of the Orange County, VT, copper mines, and he successfully carried out several firsts in American copper smelting. He was granted a patent for copperas production in 1827 that may have influenced practices at South Strafford. Tyson was inducted into the National Mining Hall of Fame in 1996 (Johnsson 1996:1-2).

Ore from the North Open Cut and new Lower Adit was cobbed, or broken up by hammer and sorted to upgrade the amount of copper, at the mine works on Copperas Hill. The lean ore was used for the copperas production, and the copper-rich ore, which contained as much as 10 percent copper, was carted down the new road to a spot near the river where it was roasted in long piles, or beds. Roasting prepared the ore for smelting by breaking it up into more permeable pieces and driving off part of the sulfur. The ore was smelted in charcoal-fueled, Continental-style, vertical-shaft, cupola-style copper smelting furnaces. These were tall, narrow, brick stacks that resembled a small iron blast furnace, with a firebrick lining, an opening near the top for charging ore, fuel and flux, an air blast pipe, and a crucible at the bottom to collect the molten metal and slag. Unlike iron smelting, in which reasonably pure iron was produced in one step, copper smelting involved several steps to remove the sulfur, iron, silica and other impurities as slag, yielding metal of useable purity. The first step resulted in what is called a copper matte, which could vary widely in percentage of copper. Usually this matte was tapped off, cooled, broken up, roasted, and smelted again in steps that produced a series of increasingly pure material, black copper, then blister copper, either of which could be cast into pigs. These products were not usually pure enough for crude applications and were usually refined, first in fire refining methods, and later electrolytically.

The nine different smelters that operated at the Elizabeth Mine between the 1830s and 1918 did not all produce pig copper. Refining matte to pig copper was extremely energy-intensive because of the fuel required, and shipping fuel to the Vermont copper mines was a constant and significant economic factor in their survival. The 1830s Tyson operation produced pig copper as there were no other smelters in the U.S. at the time that could refine copper matte. The arrival of the railroads to the Strafford area in the late 1840s presented more options, as fuel was easier to ship in and copper matte was easier to ship out to new East Coast smelters, including the Revere Copper Company's 1844 Point Shirley smelter in Winthrop in Boston Harbor, the Humphreysville Copper Company established in 1849 in Seymour, CT, and others in Baltimore and New Jersey.

When Isaac Tyson took over the Furnace Flat smelter in May 1833 the works included a dam and waterpower infrastructure, roast beds, charcoal fuel kilns, ore roast beds, and at least four smelting furnaces. Tyson used the furnaces at South Strafford for experimenting with fuels, fluxes, furnace configurations, and ore treatments. In an early attempt to profit from extracting all the values in the ore, he also experimented with making sulfur, paint and sulfuric acid from the waste materials. It appears that there were as many as seven, and perhaps even eight furnaces, and an account notes that at one point six were operating simultaneously, and that each could smelt between 5 and 6 tons of ore per day. The works employed about 200 men. No production figures for this plant exist, and estimates are difficult. The total 1830 copper output for the U.S. and Canada combined was 50 tons, and in 1840 it was 100 tons. However, the documentary evidence alone suggests that this remote, mineside smelting plant was an unusually large and unprecedented operation. It cost $25,000 to construct, and was valued at $60,000. Despite the remote location and problems with fuel supply and transportation, Tyson succeeded in several major accomplishments for American copper metallurgy, including the first use of anthracite and hot blast for copper smelting, the first successful large-scale smelting of sulfide ores in a masonry-lined furnace, and what may have been the first successful mine-side smelting of copper. Tyson received a patent for the anthracite and hot blast process in April 1834 (Abbott *GMC* 1964:22-25, Early Copper Smelting in Vermont, 1965:233-242, Vermont's Pioneer Copper Plant, 1964:33-41, Johnsson 2001, *Journal of the Franklin Institute* 20, 1835:407).

The 1833-1834 time period was critical for the development of hot air blast and the use of anthracite in smelting, when both innovations were first used and patented for both copper and iron smelting. Tyson was on the cutting edge of these developments. Because of its high iron content, chalcopyrite was a particularly difficult copper sulfide ore to smelt. Previously smelters had worked copper sulfides such as chalcocite, which was higher in copper and contained no iron. Prior to the 1830s the bulk of U.S. copper ores were shipped overseas, primarily to Wales, to be smelted. Copper was not typically smelted at mine sites, at least not with success equivalent to Tyson's, because of fuel and transportation obstacles.

The Panic of 1837 affected the Furnace Flat copper smelting works, which were shut down by 1839. In that year the Vermont Mineral Factory Company and the Green Mountain Manufacturing Company merged to form the Vermont Copperas Company, with Amos Binney, Jr., and several members of the Reynolds family at the helm. The new Reynolds family had been involved in the mine since 1813, and John Reynolds, Jr. was the business agent from the 1830s to the 1860s (Abbott *GMC* 1964:34-35).

4.3.1 Historical Significance

Of the nine smelting campaigns that took place at four locations at the Elizabeth Mine, this 1830s Tyson campaign is one of the two most significant ones from a historical and technological standpoint. It was an ambitious and unusually large operation in Ameica for its time. It was the site of several technological firsts, including the first use of anthracite and hot blast for copper smelting in America, the first successful large-scale smelting of pyritic sulfide ores in a masonry-lined furnace in America, and what may have been the first successful mine-side smelting of copper in America. Although there are other surviving later smelting sites associated with the Elizabeth Mine, this site is unique for the mine, for Vermont, and for the United States for its early date and size.

4.3.2 Known and Expected Resources

4.3.2.1 Current Landscape and Visible Features

The 1830s Tyson smelting area at Furnace Flat is located in a bend on the south side of the Ompompanoosuc River approximately 1 mile north of the mine and roughly 2 miles east of the village of South Strafford on Route 132. The site includes a road from the mine, and a roast bed area indicated by reddish, discolored earth, located just above the smelter site. The smelter site is located on an overgrown river terrace. A row of four mounds of brick and masonry debris, possibly the smelting furnace bases, are visible, as are traces of slag and a possible raceway trench.

4.3.2.2 Expected Resources

The documentary evidence indicates that this part of the site has the potential to include fieldstone foundations of the smelter building and other associated structures, a loading platform, a dam, waterwheel pit, raceways, remains of as many as eight smelting furnaces, matte roasting furnaces, slag, charcoal kilns, experimental paint, acid and sulfur apparatus and a small residential hamlet.

4.3.3 Physical Integrity

This part of the site is located on river terrace and may have been impacted by flooding episodes. It has been undeveloped since it closed in the late 1830s. It is possible that masonry was removed to build structures elsewhere, including later smelter buildings located across the Ompompanoosuc River, but belowground foundations and other related features could exist. The slagheaps in this area are said to have been excavated for road improvements around World War I, and the impact of this activity on the site is unknown (Abbott 2001).

4.3.4 Research Value and Interpretive Potential

The presence of the line of four masonry mounds suggests that there may be undisturbed subsurface remains of the smelter plant, and that the site may have high research value because of its potential to reveal information about early nineteenth-century copper smelter plant layout and processes. Few detailed written descriptions of the equipment or processes used at this operation are known to exist and archeological evidence is currently the greatest potential source of information about this activity area and period of significance.

Because of its overgrown condition, minimal visible remains and unknown belowground contents, it is not possible at this time to make definitive statements regarding this sites interpretive potential. Further historic and archaeological investigations are needed to determine the extent and physical condition of belowground components that would contribute to the research and interpretive value of this part of the site.

4.4 Copper Smelting at Furnace Flat North Bank 1854-1867, 1884

In 1854 the Vermont Copperas Company resumed efforts to smelt copper from South Strafford ore at Furnace Flat. This activity took place on the north bank of the Ompompanoosuc River, west of the 1830s Tyson smelting plant. Ore came from the North Open Cut, and from the Upper Adit and new Lower Adit. The ore was hand cobbed at the mine, and roasted either at the mine and/or along the road built to the 1830s Tyson smelter, which was extended over a bridge to reach the north bank. The product was mainly matte copper shipped out to coastal smelters, but may have included some pig copper. By the late 1850s the smelter was producing roughly 5 tons of metal per month, and by 1860 the company had built another furnace and produced 60 tons of copper that year. During the Civil War the Vermont Copperas Company may have operated as many as four furnaces at this site. Several shades of red paint were also manufactured from waste from the copperas plant. It appears that copper smelting ceased in 1867 when prices slumped after the end of the war (Abbott *GMC* 1964:35, 271-272, Johnsson 2001). The 1874 Vermont Copper Company map shows the layout of this area (Figure 4.4).

About 1884 the Strafford Mining Company, which owned the copperas works and associated mine workings at the time, erected a blast furnace type smelting furnace, possibly a water-jacketed model, at Furnace Flat on the north side of the Ompompanoosuc River and smelted on a small scale. The ore was taken from the North Open Cut, Upper Adit and Lower Adit, cobbed at a cobbing shed at the Upper Adit, roasted, and carted to the smelter. The product was copper matte, which was shipped by rail to off-site refineries. After it was shut down this furnace was dismantled and re-erected at the Ely Mine (Abbott *GMC* 1964:276-278, Johnsson 2001).

The water-jacketed smelting furnace was an incremental, but important advance in late-nineteenth-century metal smelting technology. Smelting furnaces had previously been lined with thick layers of acid silica firebrick that burned out quickly and had to be replaced frequently. The adoption of water-jacketed hearths, which consisted of hollow cast or wrought metal plates filled with circulating water that surrounded the hearth, resulted in the reduction in the amount of brick needed to line hearths and corresponding reductions in firebrick consumption and downtime for furnace relining. This technology was already making inroads in iron and copper smelting furnace construction by the early 1880s and their use at the Elizabeth Mine in the 1880s cannot be considered an innovation, but it does indicate that mine managers were keeping pace with industry improvements.

As both the 1860s and 1880s phases of operation occurred on the same site, they will be discussed together although they are slightly out of chronological order for operations at the Elizabeth Mine.

4.4.1 Historical Significance

This site is significant as a surviving smelter site associated with the Elizabeth Mine and with Civil War-era industry. It is one of several smelter sites at the mine, and was not the site of any significant technological developments, but it is important as an example of a mid-nineteenth-century water-powered industrial site and smelting site, and a Civil War-era metallurgical plant, an unusual historic industrial resource for Vermont and New England.

4.5 Known and Expected Resources

4.5.1 Current Landscape and Visible Features

This site is located in a long, narrow, oval-shaped area of flat, wooded river terrace bordered by the Ompomanoosuc River to the west and Route 132 to the east. Visible resources include the remains of a breached fieldstone dam, a fieldstone sawmill foundation, scattered copper smelting slag, numerous foundations and linear arrangements of rough cut stone, red brick, silica firebrick, large blocks of refractory soapstone furnace lining blocks with fused slag surfaces, rows of iron hoops for wood stave penstocks, stone machinery bases, vertical square steel rods, fused firebricks on mortared fieldstone walls, parallel arrangements of timber beams and logs, linear mounds of discolored red earth and fieldstone bridge abutments on both sides of the river.

4.5.2 Expected Resources

Based on the historical record and the extensive visible remains, this site could be expected to include additional features associated with the copper smelting operations as well as domestic sites associated with the workers village at Furnace Flat.

4.5.3 Physical Integrity

Much of the site is on an elevated river terrace and may have been impacted by a few high water events and erosion on its south edge, and a narrow portion of it may have been buried by road embankment construction on its north edge. However, the core of the site is relatively undisturbed with extensive visible remains at the surface. The extent of the impact of the 1884 smelter on the earlier 1850s-1860s smelter is unknown, but it is likely that the later operation utilized at least a portion of the earlier infrastructure.

4.5.4 Research Value and Interpretive Potential

Based on the extensive visible remains at the surface, this site has high research value because of its potential to reveal information about mid-nineteenth-century water-power infrastructure, copper smelting and associated activities. It may also include buried foundations and other domestic resources associated with the small hamlet of Furnace Flat that stood around the smelter. No detailed written descriptions of the equipment or processes used at this site are known to exist and archeological evidence is currently the greatest potential source of information about the activities that took place in this part of the Elizabeth Mine site.

This part of the site also has interpretive potential because of the extensive visible surface remains and its accessibility adjacent to a public highway. A historic plaque indicating the association of Furnace Flat with Isaac Tyson and the Elizabeth Mine has been designed for the site, but has yet to be erected.

4.6 Copper Smelting Efforts and Experiments 1880-1905

4.6.1 Copper Smelting at Sargent Brook 1882-1890

After the Strafford Mining Company copperas works at Copperas Hill closed in the early 1880s, activity at the mine focused again on copper. During the 1880s the Tyson family returned. Isaac Tyson, Jr., had died in 1861, leaving his business to his sons James and Jesse. James Tyson inherited the Vermont copper properties that his father had held onto, and slowly acquired additional land during the 1860s and 1870s, including the area immediately north of the New England Chemical Manufacturing Company copperas works property line. The land that he had acquired was transferred to the new Elizabeth Mining Company, named for James wife. James W. Tyson acquired the Buena Vista property on Mine Road about 1882 and made it a seasonal home. For more than 20 years the Tysons developed the mine and smelted copper in several furnaces. They did not produce high volumes of copper, but did make contributions to copper smelting technology (Abbott *GMC* 1964:276-278).

The New England Chemical Manufacturing Company would not allow the Tysons to use the Upper Adit or Lower Adit to access the orebody, so the Tysons undertook their own development work north of the North Open Cut, which by then had been excavated into a massive open trench. About 1880, Cornish mining Capt. John Vial began sinking a new 160 ft deep shaft just east of the top of the hill for the Tysons. Eventually the workings included a manway immediately north of the North Open Cut, a shallow adit, Shaft No. 1 just to the north, and Shaft No. 2 several hundred feet further north. Shaft No. 1, or the Tyson Shaft (Figure 4.5), was operated with a steam engine-powered hoist, and Shaft No. 2 was operated with a horse-whim. The ore was crushed in a Blake jaw crusher, screened and hand cobbed. It was then hauled west to the crest of the hill on a short tramway, and hauled down the west slope of Copperas Hill to several roast beds along a road leading to the smelter site on the brook. It was roasted in 24- by 50-ft beds for 11 weeks before being taken to the smelter (Abbott *GMC* 1964:276-278, Johnsson *Tyson Years* 2000:5-6).

Tyson built a new smelting plant on Sargent Brook at the foot of the west slope of Copperas Hill. This was the first steam-powered smelting operation at the Elizabeth Mine, and the use of steam power freed the Tysons to choose a smelter site closer to the mine. The smelting apparatus consisted of a 40 ton-per-day blast furnace-type vertical smelting furnace with a 48 in diameter water-jacket cooled hearth. Between 1882 and 1884 it produced about 40 tons per day of 20 percent copper matte that was shipped to the Orford Copper & Sulfur Company in Bergenport, NJ. Some of the matte was roasted in stalls on-site and further refined to 60 percent matte and then refined to pig copper that was shipped to Birmingham, England for manufacture of brass pins. Fuel was coke purchased from the Boston Gas Light Company or from the Connellsville coke district of western Pennsylvania. In this furnace, Tysons metallurgist William Glenn carried out the first known American copper smelting experiments with basic chromite refractory material. Chromite sand was used on the hearth bottom to counteract the erosive action of the acid silica slag. This experiment ultimately failed. However, Glenn documented the efficiency of the water-cooled hearth, which was under scientific debate at the time, and developed a technique for layering the ore feed to increase capacity. Because of fluctuating copper prices the works closed in 1884. The Tysons briefly reopened the smelter at Sargent Brook between 1888 and 1890. The smelter then produced a 40 percent copper matte that was sold to the American Metal Company of New York for refining (Abbott *GMC* 1964:276-278 Johnsson *Tyson Years* 2000:5-10).

By the 1880s vertical-shaft copper smelting furnaces were evolving to handle increasing quantities of ore. They were being built larger and larger, their hearths were changing shape, and they were equipped with an increasing number of air blast nozzles. They came to be referred to as blast furnaces, which they looked more like than the foundry cupolas they once resembled. In addition to water cooling, furnace designers and operators sought other ways to increase the efficiency of the furnaces. One area of experimentation was with refractory materials. Refractories were heat- and chemical-resistant materials, usually in the form of bricks or moldable solids, that were used to line smelting furnaces to withstand the heat and erosive nature of molten metal and slag. Silica slags from pyritic copper ores were an acid substance and highly erosive when molten. They would eat through conventional acid silica firebrick rapidly, sometimes after only a week of smelting, as the iron consumed the silica from the firebricks. During the late nineteenth century the ferrous and non-ferrous smelting industries were experimenting with chemically basic refractory materials including chromite and magnesite. These materials offered longer refractory life, allowing longer furnace campaigns and less downtime for relining, increasing productivity. Success with these materials led to the development of the basic open hearth, which revolutionized steelmaking, and the copper converter, which reduced the number of intermediate refining steps previously required to refine copper matte to pig copper.

4.6.2 Historical Significance

This site is highly significant as a mining and smelting site associated with the Elizabeth Mine. It was not the site of any significant technological developments, but was the site of metallurgical experiments carried out by the Tysons that were documented in the technical press of the time and represented incremental advances in metallurgical practice. It is significant as an example of a mid-nineteenth-century copper mining and smelting site, an unusual industry for Vermont and New England.

4.6.3 Known and Expected Resources

4.6.3.1 Current Landscape and Visible Features

The resources associated with the Tysons 1880s Sargent Brook smelting campaigns start at TP 3 at the east shoulder of Copperas Hill just north of the North Open Cut, and extend west approximately 3/5 of a mile to the east bank of Sargent Brook at the west foot of Copperas Hill. The area at the top of Copperas Hill is an open area devoid of vegetation, with bright yellow soil and scattered brownish purple lumps of pyrrhotite ore and burnt coal cinders. The manway is a small open vertical shaft located just north of the North Open Cut. A small depression with some timber inside located several hundred feet to the north may be the site of the Tyson Shaft No. 1. Several hundred feet further north, in a wooded area is Shaft No.2, which has caved in, leaving a large sinkhole. Beyond the treeline at the west edge of this area, a road is visible and can be followed west past two roast bed areas. The road proceeds west, downhill to the smelter site. The smelter site includes evidence of roast beds, a rectangular foundation divided into four parallel sections that may be matte roasting stalls, a rectangular earthen berm with piping that may be the remains of a supply reservoir for the steam engine and water-jacket hearth cooling system, piles of timber, stone platforms, a smelter building foundation with scattered iron and steel objects including what appears to be the conical stack hood from a water-cooled copper smelting furnace, and an extensive slag heap (Figure 4.6).

4.6.3.2 Expected Resources

Expected resources include a buried adit east of the manway, foundations of the ore concentration buildings adjacent to the No. 1 shaft, footings of a short tramway that was used to haul the ore to the crest of the hill, a cart loading platform, and three farm building foundations. Based on the historical record and the extensive visible remains, this site could be expected to include additional resources associated with the copper mining and smelting operations as well as possible domestic sites associated with mine workers.

4.6.4 Physical Integrity

This site appears to be largely undisturbed with extensive visible remains at the surface, particularly at the smelter site. The proximity in time and similarity of equipment of the 1882-1884 and 1888-1890 smelting campaigns here negate the issue of one operation possibly impacting the remains of the other, and they can be considered one event for this site. However, the slagheap has been excavated and used as a source of fill by the owner, altering its size and shape. The slagheap has potential to contain pieces of machinery, tools and equipment used by the smelting operation.

4.6.5 Research Value and Interpretive Potential

Based on the extensive visible surface remains, this site has high research value because of its potential to reveal information about late-nineteenth century copper mining and smelting and associated activities, and its potential to also include foundations, machinery fragments and additional evidence of operations. Documentary information detailing the equipment and processes used at this part of the site exists in private archives and industry periodicals. This information could be compared and contrasted to the potentially rich archaeological record as a means of generating research questions about these types of activities that would contribute to a greater understanding of this site component.

The extensive visible surface remains including mine openings, transportation routes, evidence of process and support infrastructure, and the linear orientation of the resources suggest that this site from the top of Copperas Hill at TP 3 to Sargent Brook has a high interpretive potential for the understanding of the entire process of mining, transporting, roasting and smelting copper ore and disposal of slag.

4.7 Early Twentieth Century Mining and Smelting in the Copperas Brook Valley 1895-1919

The history and resources associated with industrial activity in the Copperas Brook Valley between Copperas Hill and Gove Hill, which includes the area in and immediately around TP 1 and TP 2, is complex. This area was utilized by several companies for several phases of milling and smelting between 1900 and 1958. Therefore, the resources for each chronological phase are evaluated separately rather than collectively for this part of the Elizabeth Mine site.

4.7.1 The Elizabeth Mining Company 1895-1902

In 1886 Boston-based copper metallurgist Henry M. Howe visited the Elizabeth Mine and recommended improvements including driving a new, long adit from the base of Copperas Hill to reach new ore reserves, and installation of a large semi-pyritic smelting furnace to make 90 percent black copper, or using a Bessemer converter to make high-grade matte. The Tysons were not in a position to make those improvements at that time, but reexamined Howes findings in 1895. In November 1895, the Tysons began to drive a new adit located below Mine Road northeast of the copperas work site at TP 3. The work was carried out by hand at first and later with compressed air drills. The 1,400 ft adit reached the orebody in 1898, resulting in the opening being called the 1898 Adit (Figure 4.7). This development allowed access to more than 300,000 tons of ore and was used after enlargement until the last days of operation in 1958 (Johnsson *Tyson Years* 2000:8-13).

In 1899 copper prices rose and the Tysons built a timber frame ore concentrator mill and smelting plant northeast of the adit (Figure 4.8). Construction was ongoing while the company directly shipped richer copper ore opened up by the new adit to the Mountain Copper Company, Ltd. smelter in New Jersey. The concentrator mill was located east of where the World War II Compressor House and Workshop now stand, where the north tip of TP 2 meets the southwest tip of TP 1. The concentrator mill included a crusher as well as picking tables or belts for hand-sorting the ore, and conventional gravity separation equipment. It is unclear how much waste tailings this mill generated or where they were deposited, but it is likely that it generated a moderate amount that may be in the vicinity of the north tip of TP 2. North of the mill were roast beds served by parallel sets of railroad tracks to facilitate gravity loading and unloading of ore. The smelter plant was located to the northeast and included one each of three types of furnaces for the successive refining stages: a 150 ton water-jacketed blast furnace to produce copper matte, a 40-ton matte furnace to upgrade the matte, and a 10 ton reverberatory furnace to make pig copper of black or blister grade. The roast beds and smelter site are now under TP 1. In 1900, the smelter products were sold to the Bridgeport Brass Company and refined for them at the Nichols Chemical Company on Long Island. Despite the new mine plant the operation was not profitable. The company was cash-short and behind on payments. Fuel shortages and transportation difficulties continued to be a problem. The Tysons paid off their mortgage in 1899, only to see the price of copper fall steeply. James Tyson died in 1900 and his son, James Jr., was appointed receiver for the mine. The Tysons sought a buyer for the mine but turned down the offers. Fairly continuous smelting and exploratory work continued until June 1902 when the works were shut down (Abbott *GMC* 1964:278-28; Johnsson *Tyson Years* 2000:12-14).

Despite these hardships Tyson and Glenn made several technological innovations. Two of Tysons furnaces were equipped with experimental basic chromite linings. Instead of chromite sand, Glenn installed a solid bottom of rock chromite ore in their 3 ft by 10 ft blast furnace. This lining functioned for more than 26 weeks where regular silica brick usually lasted only one week. The reverberatory furnace was also equipped with a chromite lining that proved equally effective. The reverberatory furnace was constructed so that the fuel did not come into physical contact with the ore, unlike the cupola and blast furnace, where they were mixed. The techniques of operating the reverberatory, or English type copper smelting furnace had earlier been kept secret at English custom smelting operations such as those at Swansea, Wales, and were only used on a large scale in the U.S. at Baltimore after the 1850s. This method eventually spread to general copper smelting practice as a way of obtaining high-purity copper. In the Tyson blast and reverberatory furnaces William Glenn achieved the first successful use of chromite copper smelter linings in America. Although Glenn is not officially credited with the invention of chromite refractories, he did share his findings with the American Institute of Mining and Metallurgical Engineers (AIME) in 1901 and chromite was subsequently widely adopted for copper smelter furnace linings. Another of Glenn's innovations was made in copper converting, one that eliminated the time and energy-consuming process of roasting copper matte once it came from the blast furnace. He succeeded in eliminating this step by treating copper matte from the blast furnace by blowing a mix of superheated air, steam and silica sand on the molten metal in the reverberatory furnace, skipping the matte furnace entirely. The durability of the chromite linings was an important factor in the success of this method. Unfortunately Tyson and Glenn were unable to get a patent for this Areactor process, and a different process of copper conversion using the Pierce-Smith convertor (with chromite linings) became the preferred method (Johnsson *Tyson Years* 2000:15-17).

4.7.1.1 Historical Significance

This period of activity is significant as the last period of involvement of the Tyson Family, which had been involved in mining and smelting at this site since the early

1830s. It is significant for the technological experiments carried out at the smelter, most notably the influential successes with chromite refractory furnace lining materials. The 1898 Adit does not express that technology or significance, and the actual site of the smelting works is currently buried under TP 1.

4.7.1.2 Known and Expected Resources

4.7.1.3 Current Landscape and Visible Features

The landscape associated with the milling and smelting during this period is almost entirely under TP 1 and TP 2 (see discussion below for chronology of TP 1 and TP 2). Known resources associated with this phase of operations at the Elizabeth Mine site include the fieldstone portal of the 1898 Adit. This rectangular mine entrance tunnel has a mortared fieldstone face, concrete lintel, and long, gently sloping perpendicular fieldstone wingwalls supplemented by remains of World War II mine service piping. Similar stonework around the base of the World War II-era primary crusher to the north may be the remains of a foundation or structure built for these operations.

4.7.1.4 Expected Resources

Most of the expected resources associated with this phase of operation were located in the area under TP 1 and were likely altered by later mining activities that took place before, during or after the installation of the World War II plant. The southwest tip of TP 1 appears to touch or cross through the footprint of the Tyson mill east of the World War II Compressor House and Workshop. This mill was torn down to make way for the World War II surface plant. It was a large timber-framed building with fieldstone foundations and unknown interior levels and configuration. The presence of intact belowground remains of this mill building is currently unknown. One other structure dating from this period, a blacksmith shop, stood near the Tyson mill location, at the southwest tip of TP 1 and the North Tip of TP 2, until very recently. The site of this building has archaeological potential to contain information about blacksmith shop construction and operation at a mining site.

4.7.1.5 Physical Integrity

The remains of structures and features associated with this period of significance have a poor likelihood to retain their physical integrity because of their removal and/or burial during later phases of mining. Their belowground physical conditions are currently unknown. The 1898 Adit portal retains its integrity and is a valuable survivor of the 1895-1902 period of site activity.

4.7.1.6 Research Value and Interpretive Potential

Site elements and features for this period of activity in this area could be present under TP 1. The extent and physical condition of any such resources is currently unknown. The potential exists for remains of the base of the mill building and other associated resources at the southwest tip of TP 1 and the north tip of TP 2. There is potential for archaeological remains of ancillary buildings and structures in areas undisturbed by later mining activity, and of associated domestic sites in the vicinity. Documentary information detailing the equipment and processes used at this part of the site exists in private archives and industry periodicals. This information could be compared and contrasted to the archaeological record to contribute to a greater understanding of this phase of operations.

The 1898 Adit has interpretive potential as an intact mine entrance and apparent lone intact resource from this period of activity.

4.8 Early Twentieth Century Experiments and Ventures 1904-1930s

U.S. demand for copper rose sharply at the end of the twentieth century because of the increasing spread of electrical communication and power technology. As high-grade copper deposits were quickly worked out, the need for more and more copper drove metallurgists to develop processes to efficiently extract copper from leaner and leaner ores and even from slag, mill tailings and old waste rock. New processing technology, electrically powered equipment and the application of mass-production techniques allowed savings in fuel and labor and the realization of greater and greater economies of scale in mining. Ultimately these advances made possible the profitable mining and milling of immense low-grade deposits in open pits. Some of the new processes that were tried out in the Vermont Copper Belt included magnetic separation, pyritic smelting, and froth flotation. None of the Vermont trials of this equipment were on the cutting edge of technology or influenced subsequent metallurgical practice. They were incorporated there simply in a dogged effort to make a known large copper deposit a paying proposition. The reasons for failure included idiosyncracies in the ore, dramatic accidents, and poor capitalization and transportation.

Magnetic separation was an old idea that had been used successfully in iron ore enrichment as early as the early nineteenth century, for instance at the Franconia, New Hampshire, iron furnace. It experienced a revitalization and successful application with the advent of industrial electrification but the Elizabeth Mine's pyrrhotite proved difficult to magnetize and the process failed at South Strafford. In the semi-pyritic and pyritic smelting process, the ore roasting process was skipped and the smelting furnace was tailored to burn the sulfur in the ore itself to augment or replace conventional coke fuel. These processes were successfully applied by the metallurgical industry but were not particularly successful at the Elizabeth Mine. Froth flotation, discussed below, was successfully used at the Elizabeth Mine.

4.8.1 Judson & Rowand 1904

In 1904 John H. Judson and Lewis G. Rowand of New York, who were both involved in the development of the Wetherill electromagnetic ore separator and also had connections to the New Jersey Zinc Company, leased the mine from the Tyson receivers. They set up a pilot plant to test electromagnetic separation of the pyrrhotite from the milled ore, but the process, which also involved roasting the ore, was a failure. This pilot separator equipment was apparently set up in the vacant Tyson concentrator mill north of the 1898 Adit (Abbott *GMC* 1964:278- 281). As this equipment was set up in the Tyson mill, no surviving resources are known or expected. It is unclear how much mill tailings this experiment generated or where they were deposited, but it is likely that it generated a negligible amount that may be under TP 2. This experiment was not significant, as it was an application of a reasonably established technology to an unworkable ore, but is related to the successful application of magnetic separation carried out at Pike Hill in 1907-1909.

4.8.2 Vermont Copper Corporation 1905-1909

In 1906 The Elizabeth Mine property was purchased by August Heckscher (1848-1941). Heckscher, a German native, came to the U.S. to join relatives mining anthracite coal in Pennsylvania. Heckscher was a founder of the Lehigh Zinc and Iron Company and was instrumental in facilitating "The Great Consolidation" of several zinc mining concerns into the New Jersey Zinc Company. Heckscher's consolidation led to NJ Zinc's rise to become one of the largest zinc producers in the U.S. Heckscher resigned as NJ Zinc's general manager in 1904 to pursue other projects including reinvigorating the Elizabeth Mine. August Heckscher has been nominated to AIME Mining Hall of Fame (nomination pending) (Johnsson *Heckscher* 2000:1-2). Heckscher brought all the holdings of the various companies that had owned land at the Elizabeth Mine and consolidated them under the Vermont Copper Corporation, with James W. Tyson, Jr. as superintendent. Ore was brought out through the 1898 Tyson Adit. Heckscher brought the conventional separation equipment in the Tyson mill back on line, and built a system of elevated tramway trestles for moving ore from the 1898 adit to the smelter. Heckscher built a new large 300 ton pyritic smelting furnace, which was designed to use the sulfur in the ore as a fuel. The smelter gases were carried off by a 400 ft long brick flue with a 125 ft tall brick chimney (Figure 4.9). The site of the smelter, flue, stack, trestles and a boarding house are now buried by Tailings Pile 1. The smelter began operating in late 1908. However, in February 1909 the wooden smelter house was destroyed by a fire started by a splatter of molten metal. Heckscher promptly constructed another furnace with a steel building by August, but an explosion in the waste gas flue blew out about 100 ft of brickwork a few months later. Extensive diamond drilling of the property was conducted in 1909. No smelting ensued and in 1913 a quantity of slag was shipped out for copper recovery. It is unclear how much waste tailings the concentration mill generated or where they were deposited, but it is likely that it generated a moderate amount that may be under TP 2. About 1908, a road was built from the smelter site east to Pompanoosuc (Abbott *GMC* 1964:281-282).

In keeping with the new industrial power applications of the early twentieth century Heckscher's entire operation was powered by electricity. Heckscher established the Sharon Power Company, and built a dam and hydroelectric plant on the White River below Sharon (Figure 4.10) and a transmission line to the mine. This power was not distributed to the local community. The power station, which was located approximately 12 miles south of the village of Sharon, was destroyed in the great Vermont flood of 1927. The ruins of the breached dam, an ogee-profile, reinforced concrete structure, are still visible. It is unknown whether there are any visible remains of the power station. Heckscher also ran a water line to a pump house on the south bank of the Ompompanoosuc River, east of the area where Isaac Tyson smelted copper in the 1830s.

4.8.3 Historical Significance
This period of activity is significant as an example of the early application of electricity to rural industry, and the ruins of the Sharon Power Station, a discontiguous resource, are the most visible evidence of that technology.

4.8.4 Known and Expected Resources

4.8.4.1 Current Landscape and Visible Features
The landscape associated with the milling and smelting during this period is almost entirely under TP 1. Known resources associated with this phase of operations at the Elizabeth Mine include the fieldstone portal of the 1898 Adit that was used during this phase of operation, but built by an earlier owner.

4.8.4.2 Expected Resources
Most of the expected resources associated with this phase of operation are located in the area under TP 1 and were likely altered by later mining activity that took place before, during or after the installation of the World War II plant. The southwest tip of TP 1 and the north tip of TP 2 appear to touch or cross through the footprint of the Tyson mill, which was utilized by this operation. The smelter flue and stack, which appear in a 1939 aerial photograph, were located near the north edge of TP 1.

4.8.5 Physical Integrity
The aboveground remains of structures and features associated with this period of significance have unknown physical integrity because of their removal and/or burial during later phases of mining. The 1898 Adit continued to be used during this period, and as noted above, the portal retains its integrity and is a valuable survivor of the 1895-1902 period of site activity.

4.8.6 Research Value and Interpretive Potential
Site elements and features for this period of activity in this area could be present under TP 1 and TP 2. The extent and physical condition of any such resources is currently unknown. The potential exists for remains of the Tyson mill building and other associated resources at the convergence of TP 1 and TP 2 as noted above. There is potential for archaeological remains of ancillary buildings and structures in areas undisturbed by later mining activity, and of associated domestic sites in the vicinity. Documentary information detailing the equipment and processes used at this part of the site exists in private archives and industry periodicals. This information could be compared and contrasted to the archaeological record to contribute to a greater understanding of this phase of activity.

If archaeological resources exist in this part of the site and they possess good physical integrity, then they could be of interpretive value. The Sharon Power Company Dam ruins do have interpretive value as an example of early-twentieth-century rural electrification.

4.9 Vermont Copper Corporation 1916-1919

In 1916 copper prices rose because of World War I demand and August Heckscher reopened the mine and again attempted pyritic smelting with an improved furnace. In 1917, the General Engineering Company set up new flotation equipment for the Vermont Copper Corporation. About 300,000 to 350,000 lbs. of copper matte were produced in the new smelter. This operation was only feasible because of inflated copper prices during World War I, and in 1919 the price of copper fell. The company decided to abandon the pyritic smelting efforts because of remoteness from fuel and flux, and threats of a lawsuit from a neighbor anxious about potential smelter fume damage to his property. The smelter was located higher up on the east flank of Copperas Hill above the earlier Heckscher smelters, and escaped burial under TP 1. There is evidence of this smelter in the form of an area of slag-encrusted concrete with twisted square reinforcing bar and numerous bricks. It is unclear how much waste tailings the flotation mill generated or where they were deposited, but it is likely that it generated a moderate amount that may be under TP 1 or TP 2. (Abbott *GMC* 1964:281-283). The 1939 aerial photograph shows a roughly one acre area in this vicinity that appears to be early flotation mill tailings (Figure 4.11). The location and relationship of the 1895-1902 Tyson works and 1908-1909 and 1916 Hecscher operations are shown in a historic map (Figure 4.12).

This operation was the first to use froth flotation technology at the Elizabeth Mine. The development of froth flotation technology, first used commercially in Australia in 1905, is considered the birth of the modern mining industry. The process relies on the attraction of fine particles of metallic ore to bubbles. The process involves tumbling metallic ore in a series of rod and ball mills, large electrically driven rotating drums filled with steel rods or balls to grind the ore into talcum powder consistency. The fine ore is then added to tubs filled with water and special flotation reagents, and agitated with rising bubbles and motorized paddles. The metallic ore particles are attracted to the floating bubbles that rise to the top and are skimmed off, and the fine waste rock mill tailings are removed from the bottom of the flotation chambers. The first commercial froth flotation mill in the United States was installed at the Black Rock Mine at Butte, MT, in 1912. In 1914, three years before the General Engineering Company set up the Vermont Copper Corporation mill, there were 42 flotation mills operating in the U.S. (Bunyak 1998:29-30).

4.9.1 Historical Significance

This site is significant as the only physical remains of a smelting furnace from the twentieth-century operations in the Copperas Brook Valley area at the Elizabeth Mine.

4.9.2 Known and Expected Resources

4.9.2.1 Current Landscape and Visible Features
The only known visible resource associated with this smelting campaign is a patch of slag-encrusted concrete with twisted square reinforcing bar, located in the woods north of the World War II-era mill buildings.

4.9.2.2 Expected Resources
There is potential for the belowground remains of ancillary buildings and structures in areas undisturbed by later mining activity, and of associated domestic sites in the vicinity. Additional remains of the smelter plant may exist on the hillside north of the World War II mill.

4.9.3 Physical Integrity
The integrity of the surrounding area appears to be disturbed by modern dumping and earthmoving activities. However, the smelter feature is partially buried and associated remains could be present and intact belowground.

4.9.4 Research Value and Interpretive Potential
This area has moderate potential to contain archaeological data associated with the smelter feature and could yield information about early twentieth-century copper smelter furnace process and configuration. The scientific literature on this type of smelting technology is extensive; the contribution of this smelter feature to the historic and archaeological record of the site is dependent on the extent of its belowground remains and physical condition.

4.10 American Metals Company 1925

For six months of 1925 the American Metal Company, a worldwide investor in copper properties, mined 20,000 tons of ore and milled 1,756 tons of 18 percent copper concentrate. This concentrate was smelted at Carteret, NJ (Abbott *GMC* 1964:283). It is unclear how much waste tailings this experiment generated or where they were deposited, but it is likely that it generated a negligible amount that may be under TP 1 or TP 2. The statements for Known Resources, Expected Resources, Integrity, Archaeological Potential, Interpretive Potential, and Historical Significance are similar to those for the 1904 John H. Judson and Lewis G. Rowand pilot electromagnetic separation plant. The extent of site development at this time and previous historic operations appear on a 1925 real estate map (Figure 4.13).

4.11 National Copper Company 1928-1930

After the fluctuating copper market and sporadic smelting and milling attempts of the first two decades of the twentieth century, the outlook for the Elizabeth Mine was bleak. Because of the lack of accurate production information from 1830 to 1930, it is impossible to accurately determine its total refined copper output, which appears to stand between 10 million and 19.2 million lbs. This was less than the 30 to 40 million lbs. estimated for the Ely Mine, and far less than Pike Hill. Exploration had proven ore reserves in an area 13,000 ft long and 1,500 ft deep, but the ore was low grade, hard to mine and beneficiate, and remote from sources of power and transportation. One last attempt was made to extract copper ore from the mine before the onset of the Great Depression. This effort was championed by Frederick W. Foote, a mining engineer with experience in sulfide ores who was convinced that the Elizabeth Mine could be made to pay. Foote convinced backers to form the National Copper Corporation in 1928. Foote believed that the mine could be profitable if more of the values in the ore, including the iron and sulfur, could be extracted by flotation. National Copper mined and milled 60,000 tons of ore in the re-equipped old Tyson mill between April 1929 and June 1930, producing 6,330 tons of concentrates before the plant was closed because of falling copper prices. During the last two months of operation under Foote, the flotation mill reached its predicted output of 300 to 350 tons per day of 20 percent copper concentrate and recovered more than 90 percent of the copper in the ore. A view of the expanded Tyson mill as it appeared about 1930 is shown in Figure 4.14. Experiments proved that the iron-sulfur content present in the pyrrhotite could be extracted through flotation. In 1931 Foote thoroughly analyzed the mine and proposed construction of a 500 ton-per-day mill, and sulfuric acid production. Exploratory drilling revealed reserves of 1,565,00 tons of ore carrying 1.76 percent copper, enough for 10 years of operation. When National Coppers lease expired, Foote purchased the property for $50,000, and waited for market conditions to change (Abbott *GMC* 1964:283-287).

4.11.1 Historical Significance

Foote’s operation can be considered historically significant as it established the viability of the Elizabeth Mine when operated with properly designed and supervised milling procedures. It is unclear how much waste tailings this experiment generated or where they were deposited, but it is likely that it generated a moderate amount of tailings that may be buried under TP 1.

The statements for known and expected resources, physical integrity, and research value and interpretive potential are similar to those for the 1904 Judson and Rowand pilot electromagnetic separation plant and the 1925 American Metals Company flotation plant.

4.12 WW II and Korean War Era: 1941-1958

4.12.1 Vermont Copper Company, Inc. and Appalachian Sulfides, Inc.

As early as 1940 the U.S. government began to look to the Vermont Copper Belt as a potential source of strategic metals for the World War II effort, and after Pearl Harbor, interest in the Elizabeth Mine as a source of copper grew. The rebirth of the mine was championed by George Adams Ellis, a Vermont-born financier and industrialist, who worked with the Vermont War Production Board to reopen the mine. Vermont governor Stanley C. Wilson was also involved. The Vermont Copper Company, Inc., was organized in April 1942 with Ellis as president. The company acquired the Strafford, Vershire and Corinth mining properties and spent $2,350,000 worth of private investments and loans to develop the Elizabeth Mine. Frederick Foote was retained as a consultant. U.S. Bureau of Mines drilling tests showed that 16,500 lbs. of copper could be produced within two years. Abbott (*GMC* 1964:308-311).

Redevelopment work included clearing and pumping out the underground workings. By May, 200 men were employed cleaning and rebuilding the mine. The 1898 Tyson adit (at what was then renamed the 300 ft level) was straightened and enlarged for the new 3 ft gauge electric mine cars. The 300, 400, 500 and 600 ft levels were prepared for working by clearing a cavern for a work station at the end of the 300 ft level adit and installing a 250 hp hoist to pull mine cars up an 800 ft inclined shaft that led north to the 600 ft level. A ten mile paved highway (now Vermont Route 132) was built to the Boston & Maine Railroad at Pompanoosuc, a 7.5 mile electrical line was built to the mine, and a water line was run to a new pump house on the south bank of the Ompompanoosuc River, east of the area where Isaac Tyson smelted copper in the 1830s. The late 1890s Tyson-era mill and smelter buildings clustered around the 1898, or A300 ft level adit were torn down and a new complex of mine buildings was built that included a change house, compressor building, workshop, and warehouse/office in a straight line on a flat level east and north of the 1898 adit (Figure 4.15). A crushing plant, flotation mill and thickener/dryer building were located in tiers on the hillside below to take advantage of the flow of water and gravity in the beneficiation process. The 500 ton per day flotation mill was built by the Galigher Company of Salt Lake City. Other ancillary buildings included a heating plant, garage, laboratory, water tank building, high water storage building, first aid building and boarding house (for descriptions of these buildings see the previous historical report (Hartgen 2000)). In August 1942, the U.S. Government gave the mine a contract for 16.5 million lbs. of copper. Ore production began in the spring of 1943, but the mill was not ready to process ore until October. By November the system was operating 24 hours a day, but did not reach its capacity of 500 tons per day for some time because of technical difficulties. The concentration process recovered more than 90 percent of the copper in the ore and the concentrate contained 23 to 28 percent copper. It was shipped to a Phelps-Dodge Copper Company smelter at Laurel Hill, Long Island, for refining (Abbott *GMC* 1964:312-316).

The copper concentrate was shipped in at least two truckloads per day to the Boston & Maine Railroad at Pompanoosuc Station, approximately 10 miles east of the mine via Route 132. The concentrate was transferred from the trucks into railroad cars for shipment to the smelter. The station area is located on an access road off Route 5 in Norwich. Today the site includes a small rural passenger station with an overhanging hipped roof and a station agent’s bay window on the track side. This building is now a private residence. Until the advent of the automobile Pompanoosuc Station was an important satellite of the Elizabeth Mine, as it served as the closest passenger and freight station and communication center, and traffic and messages associated with the mine were handled through the station agent (Johnsson 2001; Smith 2001). The Boston & Maine Railroad took over the Connecticut & Passumpsic Rivers Railroad in 1887. After construction of Route 132 in the early 1940s it continued to be the shipment point for incoming equipment and supplies and outgoing ore. At that time the mine company constructed the copper shed opposite the station. It is a long, narrow, tall, gable-roofed building located parallel to the tracks, with the same tan asphalt siding used on the World War II-era buildings at the mine site. This building was used to store rail freight associated with the mine. This building was referred to as Pompanoosuc Depot in the previous historical report (Hartgen 2001:19).

Because of a shortage of labor during the war, and skilled labor in general, the mine did not reach full capacity for several years. Fifty miners from Newfoundland were imported to ease the labor shortage. The quality of the ore and the milling fluctuated. Mine pumps broke, and water flows became a problem. The mine produced an average of 300,000 lbs. of copper concentrate a month through 1944, for a year-end total of 3,810,881 lbs. Additional ore was mapped out below the 600 ft level and a winze, or underground shaft, was planned to reach a 975 ft level. After the end of World War II, labor shortages persisted and the price of copper fell. Production in 1945 fell to 3,777,718 lbs. In 1946, the 725 ft level was developed, new ore was mined, and production reached 6,064,572 lbs. Tramming and hoisting ore to the 1898 Tyson Adit at the 300 ft level became an inefficient way to move the ore out of the mine. A new vertical shaft was sunk about 1,100 ft north of the 1898 adit and a new adit was driven in to meet the shaft at the 300 ft level. This new adit exited just north of and above the new mill buildings, east of Mine Road. A hoist was installed that would allow the shaft to be sunk 3,000 ft and development of ore containing 10,000,000 lbs. of copper. Output in 1947 was only 4,495,054 lbs. By that year copper shortages cropped up again and the price rose, but the mine was only marginally profitable. The owners realized that in order for the mine to be profitable it would have to produce other values from the ore. A total of $250,000 was expended on experiments to extract pure iron from the mill tailings through an electrolytic process, which proved fruitless. The new shaft was completed in mid-1948, but the mine required more exploration and increased plant capacity to produce at a scale that would insure profitability, and some form of government assistance was sought. In early 1949, the company signed a contract with the U.S. government for 30 million lbs. of copper at 19.25 cents per lb. for four years, and received a $150,000 government loan (Abbott *GMC* 1964:320-326).

The new contract and new shaft promised a profitable future. The mine had been losing $15,000 to $20,000 a month for two years. The copper content of the newly developed ore was lower than anticipated and output for 1948 was only 4,415,865 lbs. The mine took on Frank Eichelberger as president and general manager. Eichelberger was a mining engineer with a reputation for running profitable operations and who had been a pioneer in the development of froth flotation. He instituted cost-cutting measures and concentrated on mining the best ore at his disposal and increasing the volume of ore running through the mill to maximize the economy of scale. In 1949, the company hauled ore from the Ely Mine waste dumps and mixed it with ore from the Elizabeth Mine. This was problematic, as the oxidized ore proved difficult to process. A recession in early 1949 lowered the price of copper to 16 cents per lb. and the Phelps Dodge refinery went on strike. By June the mine turned its first profit, and the Reconstruction Finance Corporation funded construction of a larger primary crusher plant. The capacities of the mill's various departments were tuned and matched for increased output of 750 tons per day to meet the increased ore production capacity. Copper output rose to 600,000 lbs. per month and 1949, production figures totaled 6,094,980 lbs. (*Abbott* GMC 1964:327-332).

By April 1950 the price of copper rose again and was more than 24 cents per lb. by the end of the year. New exploration proved reserves of rich ore all the way north to the Ompomanoosuc River. The South Open Cut was started at that time. This long, narrow, steeply dipping exposure of the orebody was located several hundred feet south of the North Open Cut. The contract for excavation of the ore was given to a private contractor, who blasted the ore free, excavated it with a cable-shovel and trucked it to the mill on a new road built down the east flank of Copperas Hill, across the former copperas works area. This activity did not extend underground and resulted in a long, narrow, steep-walled trench several hundred feet long, now partially filled with water. Excavation of the South Open Cut required blasting a small, perpendicular cut from the road north to the orebody to facilitate access. The waste rock from this development was dumped in a pile east of the cut and the haul road. The South Open Cut operation was short-lived, but it did provide a boost in the quantity of fresh ore for the mill. A total of 60,000 tons of Ely waste rock was also consumed in 1950. A total of 1,200,000 lbs. of copper were realized from milling Ely ore at the Elizabeth Mine. In 1950 the Elizabeth Mine produced a new record high of 7,000,000 lbs. of copper (Abbott *GMC* 1964:332-335).

In 1951 domestic sulfur shortages finally led to the realization of plans to extract sulfur from the ore under a contract with the Brown Paper Company of Berlin, NH, which wanted the sulfur for sulfite process wood pulp treatment for papermaking. The process would leave behind iron that could also be sold as a by-product. This required building an addition to the east end of the flotation mill to include extra flotation cells to remove the pyrrhotite from the tailings after the chalcopyrite was extracted. By 1952, this unit was producing 20,000 tons of pyrrhotite concentrates a year. By 1952, TP 1 had grown to fill the valley between Copperas Hill and Gove Hill to the east. When the new flotation cells went on line, TP 2, or at least its upper layers, was started south of TP 1 to keep the tailings segregated (Abbott *GMC* 1964:336-338; Condict 2001).

The price and demand for copper rose with the Korean War and in 1951 more ore was developed below the 975 ft level, raising estimates of ore reserves by 670,000 tons. In 1954, after the war, the company signed a government contract for 12,000,000 lbs. at just more than 31 cents per lb. In June of that year the mine was sold to Appalachian Sulphides, Inc., a subsidiary of Ventures-Nippissing of Canada, for $365,000. Under the new owner, mining rights increased to over 8,000 acres along the Vermont Copper Belt. The company intensively prospected for more ore at the Elizabeth and other former mining sites in Vermont and elsewhere in the Appalachian Mountain chain. The mid-1950s were highly productive for the Elizabeth Mine because of improvements in equipment and a steady labor force. Although production never reached 10 million lbs, it rose above 8,500,000 lbs. in 1954 and 1955. Monthly production rose from 300,000 lbs. per month in 1944 to more than 700,000 lbs. The mill went from producing an average of 200 tons per day in 1943 to an average of 800 tons per day in 1952. Recovery of trace amounts of silver and gold at the refinery added to income. Employment at the mine reached a high of 220 workers who lived in 16 surrounding towns. The annual payroll was more than $1 million and sales were more than $3 million. The most successful year was 1955, when the mine yielded $1,016,705 in profits (Abbott *GMC* 1964:337-339).

Mining eventually progressed north of the Ompompanoosuc River, where two openings were driven down to meet the underground workings. These openings include an air shaft and an air vent. The air shaft is an inclined shaft capped by a small, square, concrete-walled shed about four or five ft square and about as tall with a concrete lid and an opening for a suction ventilation fan. It also includes a ladder to provide an emergency exit for the mine. An adjacent electrical utility pit surrounded by a chain link fence with High Voltage signs contained the transformer for the electric fan motor. The air vent is located on the south side of the Ompomanoosuc River, opposite the 1850s-1860s smelter site. It is a vertical hole less that 1 ft in diameter topped with a flanged steel pipe. It currently drains 75 to 200 gallons of water per minute from the mine workings and is surrounded by a deposit of ferrous and aluminous precipitates.

Production dropped below 7,000,000 lbs. in 1956 and 1957. High-grade copper ore was becoming scarce, copper was again in oversupply, and prices fell from a 90-year peak in 1956. By 1957, the number of employees dropped to 180 and the payroll dropped to $800,000. Appalachian Sulphides had been using profits from the Elizabeth Mine to reopen another historic sulfide copper mine at Ore Knob, NC. In February 1958, Appalachian Sulphides closed the Elizabeth Mine and shipped much of the equipment to Ore Knob. (Abbott *GMC* 1964:339-342). The 1948 shaft entrance was capped with a concrete slab, otherwise, the mine site and buildings were left vacant. Figure 4.16 shows the final extent of the underground workings in cross section.

4.12.2 Historical Significance

The Elizabeth Mine produced an estimated 10,500,000 lbs. of copper before its World War II revival in 1943. During the subsequent 15-year campaign the mine it yielded 91,495,800 lbs. of copper, and probably had a total lifetime output of more than 100,000,000 lbs. It ultimately outstripped its nineteenth-century counterpart, the Ely Mine at Vershire. In 1953, the Elizabeth Mine was the nineteenth highest producing copper mine in the U.S. Between 1946 and 1956 it was among the top 25 producers and was twentieth in five of those years. In 1950, there were 300 copper mines in the country. The top five produced 67 percent of U.S. copper and the top 10 produced 85 percent. When it closed, the Elizabeth Mine extended 11,000 ft horizontally and had about 5 miles of underground workings (Abbott *GMC* 1964:336-340; Howard 1969).

The operations from this period left a vast landscape of dramatically altered terrain in the Copperas Brook valley east of the surface plant in the form of TP 1 and TP 2, which contain approximately 2 million cubic yards of material. These tailings piles are a dramatic component in a highly unusual industrial landscape for New England, one that includes the only intact cluster of historic hard rock metal mining buildings in the region. Among those buildings is the flotation mill, which had an average daily capacity of 800 tons. Small flotation mills have rapidly disappeared from the American mining landscape as historic mines have been cleaned up or expanded. In 1960, two years after the Elizabeth Mine closed, there were 202 froth flotation mills operating in the U.S. In 1998, the National Park Service undertook a survey of 500 to 2,000 ton-per-day flotation mills in the U.S. This survey located only five surviving mills of this size. They varied in integrity from good to poor. Only two were intact with their original equipment, and none were located east of the Rocky Mountains. The lack of equipment and deteriorated condition might rate the Elizabeth Mine's flotation mill a poor for its integrity in that study, but the unusual geographic context certainly makes the mill an exceptional resource for the Eastern U.S. (Bunyak 1998:29-30, 47-57).

4.12.3 Known and Expected Resources

4.12.3.1 Current Landscape and Visible Features

This final and most productive phase of operations at the Elizabeth Mine resulted in the greatest production of copper and a correspondingly impressive deposit of waste material. The legacy of this operation consists of a dramatic industrial landscape that includes TP 1, TP 2 and a largely intact cluster of hard rock mining buildings that include a rare surviving eastern U.S. flotation mill (Figures 4.17-4.22).

The most dominant landscape feature is the massive area of flotation mill tailings divided into two major sections called TP 1 and TP 2. These two flat-topped piles of fine-ground, orange-tan material sit astride the Copperas Brook valley east of Copperas Hill in a roughly wedge-shaped mass that is 4/10 of a mile long at its longest dimension and has a 50 ft high, 1,500 ft long sloping wall on its north side. The sloping sides are eroded into thousands of small vertical gullies that give them a corrugated appearance. TP 1 is larger and located north of TP 2. The two tailings piles are divided by the trace of an old road that cuts across them from northwest to southeast, with TP 1 below to the north and TP 2 rising up to form a second tier to the southwest. Copperas Brook has eroded a deep trench through the stepped northeast face of TP 2, and flooded out onto the east side of the top of TP 1. Groundwater has also eroded a gully along the west side of TP 1 that deepens as it reaches the north face of the pile, where the warm shed, a small outhouse-sized wood-frame shelter; a small collapsed one-story building, and a surviving utility pole are located.

The other major landscape feature is the hillside west of the tailings pile where the World War II mining company buildings are located. This hillside was extensively re-graded to create several tiers for buildings and transportation routes. An upper tier was made for the change house, compressor building, workshop and warehouse/office. These buildings contain mining artifacts such as drill cores, an electric mine locomotive, a Roots blower, and others. Immediately east of this tier, and on a slight downgrade to the north, is the right-of-way for the mine cars, which includes an earth embankment, abutments, a steel deck bridge, and a timber trestle. The ore processing mill complex includes a poured concrete crusher foundation, and a flotation mill and thickener/drier building built into the side of the hill, clearly showing how the process took advantage of gravity. The mine plant includes several other buildings including the assay house, water tank building, and others listed and described in the previous historical report (Hartgen 2000). The Pompanoosuc Station site copper shed, a discontiguous resource, is mentioned above.

The area immediately east of the 1898 Adit and the change house and compressor building is a dump area that includes several large pieces of mine equipment including an electric mine locomotive, steel ore buckets, mine hoist sheave wheels, an ore hoist skip, an ore mucking bucket, and other artifacts. Just south of the garage are components of a froth flotation cell including a tub with rubber agitation baffles.

The resources from this period are concentrated around the mill complex, however, there are some discrete remote elements. The 1948 shaft site is located on the hill above and northwest of the mill. A pump house is located on the south bank of the Ompomanoosuc River, east of the 1830s Tyson smelter site, and is connected to the mill area by a road. Furnace Flat includes the air shaft and air vent discussed above.

4.12.3.2 Expected Resources

Expected resources include the caved 1948 adit, the high voltage cable chamber, remains of additional WW II-area buildings, and other possible unknown resources.

4.12.4 Physical Integrity

The impact of natural processes, machinery removal, neglect and decay are accepted as part of the history of historic industrial and mining sites, and do not affect integrity the way they would be considered to affect traditional resources. When the Elizabeth Mine closed, most of the machinery was removed by Appalachian Sulphides, Inc., the 1948 shaft was sealed with a concrete cap, and other safety and stabilization measures were taken. Otherwise the mine site has remained undeveloped since it closed. Despite minor changes to the landscape, the Elizabeth Mine retains a sufficiently high degree of its integrity of location, design, setting, materials, workmanship, feeling and association to convey the environment and process of the mining activity that took place there. For additional discussion of subsequent impacts to the site's integrity, see the Post-Mining History section below.

4.12.5 Research Value and Interpretive Potential

The resources associated with this period of activity are comparatively recent. The technological aspects were well documented in the corporate and scientific press, and oral history has been collected from the many miners who are still alive. The potential archaeological resources in this part of the Elizabeth Mine date from the earlier periods discussed above and mostly lie under, and not within the stratigraphy that it deposited. The research value in the resources from this period lie in the surviving landscape and buildings. The tailings piles themselves are stratigraphic deposits that contain lengths of timber and concrete drains that are evidence of how they were built up over time. It is also possible that the tailings themselves retain information on their complex depositional history.

TP 1 and TP 2 have the potential to conceal site elements and features from the 1895-1930 milling and smelting activities that may be buried under as much as 110 ft of tailings in central areas. However, the perimeter areas could contain site elements and features buried at depths from close to ground surface to 50 ft. The resources include, but are not limited to the Tyson Mill, blacksmith shop and roast beds sites in the vicinity of the southwest tip of TP 1 and north tip of TP 2, and the Heckscher-era smelter, flue and stack sites under TP 1.

The mid-twentieth-century mining landscape and buildings at the Elizabeth Mine have high potential to interpret the flow and process of modern metal mining processes. The 1898 Adit, where the ore emerged from the mine, is a dramatic feature. The hillside ore milling complex clearly shows how gravity was used in the beneficiation process. The adjacent tailings piles show how the waste materials were deposited. The mine plant buildings and scattered artifacts including mine locomotives and ore buckets all have high interpretive value. This area of the mine also has strong potential to interpret mining in broader environmental and ecological contexts. The deposition of the massive tailings piles are a powerful example of the hand of man on the landscape and have the potential to demonstrate the impacts and tradeoffs inherent in extractive industry in a manner that is rare in the New England region.

4.13 Post-Mining Era: 1958-present

After owner Appalachian Sulfides, Inc., ceased mining in February 1958, they removed much of the mining and concentration mill equipment for installation at the reopened Ore Knob copper sulfide mine in North Carolina, which they mined for several years. Several of the transient management staff from the mine followed the company south, but the miners and operational personnel remained in Vermont. In 1961 Appalachian Sulfides sold most of the land east of Mine Road, including TP 1, TP 2 and the World War II-era mine buildings to a local resident, who sold several parcels to other owners beginning in 1969.

Since the Elizabeth Mine closed, the mine site has remained undeveloped. The landscape has been impacted to varying degrees by natural processes and human activity. Erosion from the headwaters that form Copperas Brook has slowly changed the surface of TP 3, exposing historic timber and masonry features apparently associated with the copperas production process both above and below the road that cuts through the tailings pile. Copperas Brook emanates from the base of TP 3, crosses under Mine Road in a modern culvert and eventually flows toward TP2. It has cut a deep, eroded trench through the top and face of TP 2, and created a pond and additional subsequent erosion to the east edge of TP 1. This erosion has exposed the segmental concrete pipe drains installed to divert Copperas Brook under the tailings piles as they grew. Water flowing along the west side of TP 1 has resulted in a deep gully at the toe of the slope. Erosion has also resulted in hundreds of small, parallel gullies down the face of TP 1 and 2 that give it a corrugated appearance. Weathering processes have leached the top few feet of TP 1 and 2, altering their original dark brown color to an orange-tan hue.

During the 1970s and most of the 1980s the top of TP 1 was a barren expanse of mill tailings sand. In 1980, the stark landscape at TP 1 was used as a backdrop for Button, Button, an anti-war theatrical production. In the mid-1980s the owner attempted to remediate the drainage problem at TP 1 by dumping organic material on its upper surface. This has resulted in the growth of grass and small trees, altering the original appearance of the tailings pile. It is also possible that the top of TP 1 was used as an illegal construction debris dumpsite by a New Jersey trucking firm about 12 years ago, which may also have contributed to the revegetation on the top of TP 1. The 1950s road through TP 3 cuts across an unstable slope and the road appears to have been built and/or repaired with fill brought in from elsewhere on site as the road embankment is full of mine-related debris, including drill core segments, that are visible in the eroded area below the roadway. This road is currently used by logging trucks. The brook that flows from TP 3 was recently channeled in the area immediately west of the bend where it crosses Mine Road directly east of TP 3.

Several of the mine buildings on Mine Road constructed for the World War II operations as well as a handful of earlier associated dwellings in the area, such as the Copper Castle and Buena Vista are inhabited and in varying condition and states of alteration. The World War II era mine plant operational buildings range in condition from good to poor. In particularly poor condition is the cluster of mill buildings. The 1948 adit entrance has collapsed. The roof of the water tank building on Mine Road and the Compressor Building collapsed under heavy snow in early 2001. For more information on the standing mine buildings, see the previous historical report (Hartgen 2000).

A considerable portion of the slagheap located on Sargent Brook associated with James W. Tyson's 1882-1888 smelter plant has been excavated and taken off site by the owner for use as fill material. This slag has the potential to contain fragments of mechanical equipment associated with the smelting apparatus. Some slag has also been excavated from the Furnace Flat area north of the Ompomanoosuc River, with unknown impact to the 1850s-1860s and 1880s smelter remains at this location.

5.0 History, Landscape and Resources of Ely Mine

The Ely Mine Site (VT-OR-14) is located 7 miles north of the Elizabeth Mine, in a south-facing, amphitheater-like valley on the road to South Vershire, approximately 1.5 miles west of the village of West Fairlee. The historic resources occupy approximately 350 acres. Vershire's pre-mining history was much the same as Strafford's. It was a frontier community through the eighteenth century, and relied on a subsistence economy with some local trade in forest products. This mine had no specific name strongly associated with it during its earliest years, and is here simply referred to as the Vershire Mine for its early period of activity. It was later called the Ely Mine, after its longest-running owner, Smith Ely. It was then briefly called the Copperfield Mine, but the name most commonly associated with it is the Ely Mine.

The Ely Mine was active between the mid-1850s and about 1905, but its primary contribution to U.S. copper mining history and production occurred during the 1870s and 1880s. In the 1870s, it was a major U.S. copper producer, and ranked as the third most productive copper mine in the country for two years of that decade. The Ely Mine included a major mineside smelting plant built in 1867 that was and expanded to become a massive non-ferrous metallurgical plant more than 700 ft long with 24 smelting furnaces. This plant often contributed more than 2 million lbs of pig copper, and sometimes more than 3 million, to annual U.S. output during the 1870s and was still productive into the 1890s. The mine's overall production stands somewhere between 30 and 40 million lbs of copper. The mine included a substantial worker's village and influenced the local economy. It was the scene of labor unrest that resulted in the Ely War. After its major period of production in the 1880s, it was the victim of fluctuating copper prices and poor management for the rest of its life. It was then the site of several abortive early-twentieth-century experiments testing new technologies aimed at efficient extraction of copper from low-grade ores and mine wastes.

5.1 Historic Overview

The Ely Mine sulfide orebody was discovered after the deposit at South Strafford. Allegedly, Betsy Richardson was playing on the slope of Dwight Hill about 1813, when her foot sank into a soft patch of red earth in the gossan over the deposit. Her relatives used this natural earth pigment to dye fabric. Minimal local copperas production apparently took place there after the discovery. In 1830 and 1831, local entrepreneurs formed two mining companies and explored the orebody in a desultory way. In December 1830, Isaac Tyson purchased mining rights in Vershire on farms north of where the gossan was discovered. By 1833, Isaac Tyson, Jr., and Amos Binney, Jr., partners at the South Strafford mine, had purchased most of the mining rights in the vicinity of the Richardson farm. Some excavation took place in the location of what later became the main shaft. Tyson and Binney inferred the northeast dip of the orebody and began to drive an adit toward it, hoping to use it for access to the ore, drainage and ventilation. After driving the adit 94 ft, Tyson and Binney gave up because of a lack of success and funds. About 100 tons of Vershire ore removed during these activities were smelted at Tyson’s smelter at Furnace Flat in South Strafford. Tyson and Binney quit the property and through the 1840s Pliny Dwight acquired much of the land on what became known as Dwight Hill, and sporadic prospecting continued (Abbott *GMC* 1964: 3, 21-21, 33-34, 41-45).

In 1853, Henry Barnard of Morristown, NY, purchased the original Richardson farm property including the Tyson mine workings and several adjacent parcels. The Vermont Copper Mining Company was incorporated in 1853 to work the deposit. In the spring of 1854, Capt. Thomas Pollard, a skilled Cornish miner, was hired as mining engineer. Pollard was familiar with this type of orebody and was one of many Cornish miners that contributed their knowledge and skill to mining efforts at Vershire, the Vermont Copper Belt, and many other mines in New England and the United States. Indeed, the presence of a number of Cornish miners in key operational positions ultimately contributed to the Vershire mine’s efficiency and profitability. The orebody at Vershire cropped out about half way up Dwight Hill and continued underground to the northeast as an irregular bed dipping about 25 degrees. Pollard oversaw excavation of a new shaft, and a second adit further down the hill, but ore continued to be removed from the main shaft near the top of the hill. Pollard extended the adit that Tyson had abandoned and encountered the orebody after digging only four feet. This adit then served as the main haulway and mine entrance until another adit with rail for mine cars was excavated farther down the hill in 1861 (Abbott *GMC* 1964:46-49).

During the first 13 years of operation, Vershire copper ore was shipped elsewhere to be smelted, first to the Humphreysville Copper Company established in 1849 in Seymour, CT, and later to the Revere Copper Company’s Point Shirley smelter, erected in Winthrop in Boston Harbor in 1844. It was also shipped to smelters in Baltimore and Bergen Point, NJ. In 1859, 300 tons of ore was shipped to smelters in Swansea, Wales. The main route of shipment from Vermont to the coast at that time was via canal boat on the Connecticut River.

The prospects for profitable operation and development of a mineside smelting works increased during the mid-nineteenth century. Although the Michigan native copper mines were increasingly important, their remoteness from Eastern markets enabled the Vermont mines to compete. Railroads reached the Connecticut River valley by the 1850s and dramatically changed the transportation situation for the Ely Mine, and ore was hauled to railhead at Ware’s Crossing near South Fairlee. The proximity to coastal smelters and value of the sulfide ore as a flux for smelting imported carbonate ores were advantages that favored Vershire copper ore mining. Increasing demand for copper, particularly for the Union forces during the Civil War, boosted the business (Abbott *GMC* 1964:49-51, 128-129).

Despite favorable prospects the Vershire operations of the Vermont Copper Mining Company were plagued by internal strife for its first 13 years. Captain Pollard and several other valuable miners left during this period. The ore bed was temporarily lost and output of ore during the late 1850s and early 1860s was sporadic. By 1864 the company was in poor financial condition. That year Smith Ely, a mine stockholder and wealthy New York furniture dealer was elected president of the Vermont Copper Mining Company. Thomas Pollard was convinced to return as mining engineer and his assistants followed. Pollard remedied ventilation problems, found the ore bed, and resumed mining. The main shaft was nearly 600 ft deep and ore was being worked on both levels both north and south of the shaft. In 1866 it was sunk another 40 feet, the surface plant was remodeled for efficiency and 3,615 tons of ore valued at $55,000 was mined. Despite falling copper prices that affected the Michigan copper mines after the end of the Civil War, the Vershire mine continued to profit, selling 4,930 tons of ore for $142,409 in 1867, resulting in a $70,000 surplus (Abbott *GMC* 1964:51, 66, 72-73).

In 1861, the mine's physical plant was described in Hitchcock's Vermont geological report. The area around the shaft included six buildings. The mine was 315 ft deep and employed 100 workers. Physical plant included a 30-x-50-ft crusher house with a steam engine-powered crusher, possibly a roll-type, which broke the ore into small pieces. In an adjacent 60-x-80-ft building the ore was cobbed, or broken by hand and separated into copper-bearing ore and barren pyrrhotite. The fine ore was treated in a classifying jig to raise its copper content, and the fines and lump ore were then packed for shipment. At least three shafts and several adits were driven into the orebody by 1860. In 1866, the company built improved tram roads from the mine to the bottom of the hill, perhaps in preparation for the roast beds and smelter built the following year (Abbott *GMC* 1964:128-130).

In 1867, the Vermont Copper Mining Company invested heavily in the future of their operation by constructing the first section of what eventually became a massive smelter plant. The work was overseen by William H. Long, a smelterman from the Revere Copper Company's Point Shirley works and son of Daniel Long, who had overseen Isaac Tyson's Furnace Flat smelter at South Strafford during the 1830s. The initial smelter plant included a 102-x-62-ft furnace building with four Continental, or German cupola-type furnaces, a 50-x-26 ft boiler house, and a 26-x-25-ft stamp house. These were completed by early 1868 and were located at the bottom of the hill south of the entrance to the mine and north of the brook. A total of 2,400 ft of tram car track was built to link the ore wash house on the hill with the ore roast beds further down and the smelter at the bottom of the hill. The 900 ft long roast beds were flanked by a massive stone retaining wall and fed by an elevated trestle. Roasting eliminated a percentage of the sulfur in the ore, a requirement for smelting. The roast bed arrangement and associated material handling infrastructure was considered the best in the country by the mining industry press. The company also built two blacksmith shops, a coke and coal house, and employed over 130 hands. In 1868, the company added three smelting furnaces and by the end of that year had smelted 1,136,400 (568.2 tons) of 95 percent pure copper for which they received $214,000. This was a major accomplishment for a mine of its size and the company declared a dividend of $100,000 the following year. The expansion dictated the need for construction of worker housing and a village began to grow around the smelter on the main road south of the mine (Abbott *GMC* 1964:73, 131-132).

By 1872, most of the coastal smelting operations in Boston, Baltimore and elsewhere that relied largely on imported ores from Cuba and South America had closed because of an 1869 tariff on imported copper ore that was enacted to encourage domestic copper ore mining. This ensured the future profitability growth of the Vershire mine, which at that time had the only active copper smelter in the Northeast other than one at Taunton, MA. The high cost of transporting fuel from the railroad at the Connecticut River to the smelter and shipping out the smelted copper were considerable factors in the profitability of the operation, and the mine consumed much local timber for heating, construction, and roasting ore and impure copper matte. Transportation costs alone in 1868 totaled $44,525. In 1872, the Ansonia Brass and Copper Company of Connecticut, founded in 1854, signed a contract to purchase the entire output of the mine, a relationship that lasted until 1883. President Smith Ely installed a new steam plant, and started excavating a new shaft and a new adit at the foot of the hill to improve access to the ore. Copper prices rose again to a peak of 35 cents per pound and the mine village continued to grow, providing housing for 300 men with a monthly payroll of almost $17,000. After the Panic of 1873 the price of copper fell to 16 cents by 1878, but this hardly affected the profitability of the mine. The Vermont Copper Company had become the most productive copper mining operation outside of Michigan and one of Vermont's biggest industrial operations. This was partly because of the richness of its ore, which contained a higher percentage of copper than the South Strafford orebody. However, its 1872 dividend of $60,000 was its last (Abbott *GMC* 1964:51, 74-85).

In early 1876, Smith Ely introduced his 21 year-old grandson, the flashy Ely Ely-Goddard, to the Vershire copper mining community with the goal of training him to oversee the mine. Ely Ely-Goddard was a product of high society, educated in Europe and inexperienced in the world of industry, much less rural society. His grandfather encouraged his conspicuous extravagance, which became a local curiosity. In 1876, the mining village was a Western-style boom town with a busy hotel, bank, stores and supporting industries. Most of the vegetation in the bowl-shaped valley had been denuded by sulfur fumes from the roast beds and smelter. This environmental damage led to lawsuits from abutting farmers. Ore roasting kilns, which provided a higher quality blast furnace feed, were added. In 1877, the Vermont Copper Mining Company constructed a quarter-mile-long smoke flue from the smelter to the top of the hill on the east side of the valley. This flue, which is still in place, consists of vertical walls and a flat roof made with flat slabs of locally quarried schist. It was topped by an 80 ft tall, lead-lined draft chimney (not extant) at the top of the hill. It is similar in cross section to smelter smoke flues constructed in Cornwall and the American West, and had a sinuous, undulating profile that hampered its ability to carry off waste smelter gases efficiently. It remains a unique example of this type of historic mining infrastructure in New England (Abbott *GMC* 1964:86-90).

In early 1876 the smelter shed was more than 200 ft long. During that year it was expanded 100 ft and contained a total of 14 smelting furnaces. That year the smelter produced 1,646,850 lbs (823.3 tons) of pig copper and the mine was allegedly the most productive copper mine in the U.S. with the exception of the Calumet & Hecla mines in Michigan. By 1877, the smelter was extended another 100 ft and two more furnaces were being installed. About 400 men were employed in the mines, at the smelter, and assisting with transportation. Many were Cornishmen, some from the Michigan copper mines. The company kept 20 horses at the mine, and another 50 hitched to 12 freight wagons. The mine included 28 buildings, and the village included 70 dwellings with 105 tenements (Figure 5.1). Approximately 1,000 people lived in the mine village and another 200 lived in outlying areas. The surrounding area was part of the mine economy and supplied food, timber, and sawn lumber (Abbott *GMC* 1964:91-93). Today, remains of the smelter plant are visible and include foundation walls and masonry furnace bases. No other buildings survive on site, however, Ely Ely-Goddard's mansion, the Methodist Church, and possibly the first Catholic Church have been relocated away from the mine area.

In August 1878, Ely Ely-Goddard was elected representative to the Vermont legislature for West Fairlee, and a plan emerged to change the name of Vershire to Ely in honor of Smith Ely. This ignited resentment against the Ely family that had been growing because of a combination of factors including their domination of local politics, economic malaise in the wake of the Panic of 1873, the town debt, lack of reinvestment in the community, and Ely Ely-Goddard's extravagant lifestyle. Vershire was renamed Ely by a vote held at an 1879 special town meeting that erupted into a fracas (Abbott *GMC* 1964:98-104).

Despite these political rumblings, the Vermont Copper Mining Company's business continued to expand. In 1878, Smith Ely purchased the Union Mine at Corinth, several miles north of the newly named town of Ely, and shipped the copper ore from this mine to his Ely smelter with 60 teams of horses. The Ely mine reached a depth of 2,000 ft. The added volume of ore required an increase in smelting capacity, and in 1879 he added another 200 ft to the building, and installed new furnaces, bringing the total to 24 by June of that year. These included furnaces of different types for the varying stages of refining the copper. The building, which included new boilers and steam engines, reached a length of almost 700 ft, and was said to be the longest building in Vermont. The slag dumps south of the smelter extended so far toward the brook that the main road had to be moved to its other side. Approximately 1,000 men with a monthly payroll of almost $20,000 worked at the Ely and Corinth properties in three shifts. More than 200 horses were used to haul ore, copper and supplies. Copper prices rose in 1879 and 1880, when the population of Ely reached its peak of 1,875 and the mine reached its accepted peak production figure of 3,186,175 lbs (1,593 tons) of copper. A new Catholic church was begun to replace the old one that had become decrepit. Ely Ely-Goddard built himself a new, extravagant house, Elysium, which was of unusual design, with a wraparound second story balcony and rooftop cupola. He imported servants and staged elaborate parties and sporting events (Abbott *GMC* 1964:104-106, 136-137).

Political events became a factor again in 1880, a presidential election year in which the Democrats, supportive of free trade, proposed to reduce the tariff on foreign copper from five cents to one cent, which threatened to close the Ely mine. Roswell Farnham, the Ely mine's attorney, was running for governor of Vermont, and Smith Ely and his grandson both shifted allegiance from the Democratic Party to the Republican Party, and warned the miners that they might lose their jobs under a Democratic administration. The Elys put pressure on the miners to vote for the Republican candidate Garfield, whose running mate, Chester Arthur, was from Vermont, and for Farnham, a ticket that would insure the longevity of the mine. This ticket was elected, along with Ely Ely-Goddard, who was reelected as representative. Regardless of this apparent insurance policy, Smith Ely, who was entering his eighties and going blind, began considering selling the mine. The combination of political events, falling copper prices through the 1880s, and a series of expensive lawsuits over property boundaries above the orebody, was eroding his energy and profits. There is some evidence to suggest that he wanted to sell the mine to fund development of a new mining investment in Nevada, and that the location of that prospect, also named Ely, is linked to him (Abbott *GMC* 1964:110-117).

In 1881, copper output dropped to 2,555,000 lbs. The mine was becoming unprofitable because of the scale of operations and needed a new infusion of capital improvements. Mining activity in the gently sloping orebody had reached a distance of 3,000 feet from the shaft headworks. The existing hoisting equipment was inadequate for this distance, and breakdowns were costly. They affected the operation of downstream processes that had to be kept running, especially the smelting furnaces, which had to be shut down. This reduced output and profits. Competition from mines in Michigan and new mines in Arizona and Montana became a serious factor. The Appalachian sulfide ore bodies typically pinched and swelled, and Smith Ely relied on the advice of his longstanding Cornish mining crew to install a new $50,000 hoist and continue driving the Ely shaft to reach better ore. Delays in installation and operational bottlenecks associated with the single shaft remote from the working faces led to serious financial losses. The price of copper fell to 18.27 cents in 1881 and the newly found copper ore proved to be of lower grade. The orebody was lost at the Union Mine, reducing supply to the smelter (Abbott *GMC* 1964:117-122).

Smith Ely informed his staff about the situation and told them that he would try to pay them while he was trying to bring the mine back into production, but many miners left. By October 1882, the Vermont Copper Mining Company was carrying almost $200,000 in debt. The Union Mine was finally abandoned in 1882 when the ore vein could not be relocated. The company placed the miners on a contract system at lower pay. In desperation, Smith Ely invited Francis Michael Frederic Cazin, a German mining engineer, to examine the mine. Cazin manipulated Ely into transferring the operation of the mine to him and Ely Ely-Goddard, and reorganizing it through creative financing as the Vermont Copper Company of New York on May 16, 1882. Unknown to Smith Ely, Cazin had purchased a number of mines in the Midwest and West that failed to generate enough income to pay for the expensive equipment he installed there (Abbott *GMC* 1964:119, 150-158).

Cazin proposed to restore profitability by reprocessing 1,155,000 lbs of copper that he estimated were tied up in the waste rock dumps, as well as low-grade ore in the mine through a new concentration mill and pyritic smelting furnaces that did not require roasted ore. Cazin managed to partially install this system but it did not prove as successful as projected. The concentration mill was built at the bottom of the hill near the village. A smelter with two furnaces was also constructed and Cazin hired Edward D. Peters, a noted metallurgist, to oversee the works. This work was presumably financed through advances made by the Ansonia Brass and Copper Company, which was still contracting with the mine. Cazin produced 406,043 lbs of copper between July 1 and November 15, at a cost of 25.3 cents when copper was selling for 16 cents. Cazin's methods were questioned by his mining captain and by the mining engineering press, who doubted that the ore could be processed efficiently according to Cazin's arrangements (Abbott *GMC* 1964:159-161).

By the end of May 1882, the miners had not been paid for three months and began a series of strikes. Cazin mistreated the miners and threatened to close the company store. Creditors doubted the solvency of the operation and called in debts, which Cazin refused to pay. Imported German and Swedish miners disturbed the peace of the village. The residents of Ely successfully petitioned the Vermont legislature to return the name of Vershire. Cazin was fired by Ely Ely-Goddard on November 3, 1882, but he refused to leave, choosing to fight the company instead. The company's funds were attached by the town for nonpayment of taxes and another creditor attached money intended for payroll. Eventually Cazin resigned, leaving the company in such bad financial shape that it could not cover its operating costs (Abbott *GMC* 1964:154-171).

In early 1883, the Vermont Copper Company, with Ely Ely-Goddard as president, attempted to get back on its feet. A reevaluation of the property offered favorable projections, but there were no men and no money to begin mining. Through a series of financial negotiations, the property, including the Union Mine on Pike Hill, was transferred back to the old company, the Vermont Copper Mining Company, which took possession on February 1, 1883. The miners had not been paid since December and the store was almost out of stocks. Mine superintendent Richard Barrett had located another rich area of copper ore. Cazin initiated a slander campaign against the Elys and was arrested. With the miners desperate for cash and the critical contract for coke smelting fuel about to expire, the mine was in desperate need of cash. The Passumpsic Railroad cut off service to the mine, shutting off the supply of fuel and goods. The miners, still unpaid in March, had developed thousands of tons of ore that could not be smelted. Daniel Long, Jr., succeeded in rebuilding some of the furnaces damaged by Cazin's overdriving, but copper production in April was only 82,000 lbs as compared to 300,000 lbs at its best. On April 28 the Ansonia Brass and Copper Company signed a new one-year contract that insured cash advances, enabling Smith Ely to sell 100,000 lbs of copper to them the same day. Unfortunately the company's creditors would not lift their attachments, and Cazin was challenging the transfer of the company's property in the courts and was agitating for receivership. His petition was ultimately denied. The company officers tried to reorganize finances to operate with a new mortgage. The company had only raised $55,000 in cash and could still not satisfy creditors and meet its full payroll for May or June 1883 (Abbott *GMC* 1964:173-197).

By June the price of copper had dropped to 15 cents a pound, and there was no cash to operate efficiently. The company suspended work on Monday, July 2. When the store opened that morning a party of about 250 miners looted it and assaulted the company watchman. The mob was dissuaded from looting Ely Ely-Goddard's house, but commandeered the mine's explosives supply. The mob gathered rocks, tools and guns and marched to West Fairlee to Ely Smith's house. Treasurer C.C. Sargent explained the company's financial predicament to no avail. They surged into the house where they were repelled at pistol point. Smith Ely negotiated with five miners chosen from the crowd, explaining to them that their predicament was Cazin's fault. Meanwhile, the mob ransacked the West Fairlee store. The miners routed Cazin, burning his house, and set a deadline of the following Saturday to be paid or they would burn the mine and the village. The company's bondholders refused to help the company pay the miners. Vermont Governor Barstow called out five National Guard companies to enforce peace at the mine, authorizing them to use force if they met with resistance. The troops marched into Vershire at dawn on Saturday, June 7. The rioters were asleep and the town was quiet. The ringleaders were arrested and the powderhouse was secured. Although no shots were fired, this dramatic event became known as the Ely War. One company of guards remained to keep the peace and the prisoners were marched off to jail. Half the miners and their families left Vershire by the following Monday (Abbott *GMC* 1964:198-224).

The Ely War resulted in the collapse of the Vermont Copper Mining Company. Samuel Gleason of Thetford Center was appointed receiver in September 1883. Cazin resumed his attempts to take control of the property. In November, Gleason asked Daniel Long, Jr., to return to the smelter to smelt all roasted ore and matte on hand to cover the mine's expenses. Desultory smelting continued into early 1884. Smith Ely died in the summer of that year and the company and Cazin appeared anxious to reach a settlement. In November 1884, Grover Cleveland was elected president and the Democrats reduced copper tariffs, to the detriment of the copper industry. Daniel Long, Jr., moved to Montpelier and took up selling stationery. The town of Vershire assessed the mine for $3,200 in taxes, and Gleason desperately sought a buyer. On May 25, 1887, the mine was sold to E.P. George for taxes and $1,041.26. The mine was then put up for auction, and the successful bidder was none other than Cazin. The Copperfield Mining and Smelting Company of New York, which included Cazin's wife as an incorporator, took over the mine. Cazin, in an attempt to erase the name of his arch-rival Smith Ely, unofficially renamed the town Copperfield. With financial assistance from a German financier, Otto K. Krause, Cazin paid off the creditors, completed the concentration mill, and purchased rock drills, railroad track and new machinery. He completed installation of the second smelting furnace, a calcining roaster for the ore, and new pumps for the mine. Cazin, however, had trouble making payroll, and the mine suffered another strike. Reportedly only 5,000 lbs of copper were shipped in 1888. Krause, who had invested $148,000 in the new works, hired an outside consultant to assess Cazin's furnace installation. In April 1889 Cazin suddenly resigned, although he was probably fired (Abbott *GMC* 1964:235-258).

In 1889, the mine was pumped out, ore mining increased, and a water-cooled smelting furnace originally used at South Strafford was installed. A total of 200 men were at work again and copper production rose from 147,000 lbs in 1889 to more than 500,000 lbs in 1890. Production rose again to more than 1 million lbs in 1891 and perhaps 1.2 million lbs in 1892. This success was achieved just in time for the Panic of 1893, a result of the Sherman Silver Purchase Act, which drove down the value of the dollar and provoked foreign disinvestment in U.S. ventures. By 1894, Krause departed and the mine shut down. The Copperfield Mining and Smelting property was appointed a receiver and maintained the property for future sale (Abbott *GMC* 1964:258-260). A panoramic photograph taken about this time shows the mine and village (Figure 5.2).

Soon the economic depression began to lift and yet a new set of speculators began to promote the mine. A new owner, the Ely-Copperfield Mining Company, included ex-Governor Roswell Farnham as president, and Robert F. Straine, president of the United Telegraph Company of Boston as vice-president and general manager. The company issued bonds secured by a mortgage on the mine, and commenced promotion. The company hired N.A. Bibikov, a Russian mining engineer, to direct the work, which began anew in August 1896. The company was unable to raise the cash to complete installation of new equipment or to pay the miners. Bibikov resigned in 1897. Again the mine was caught up in legal haggling as Straine was accused of embezzlement and a series of lawsuits ensued. The mine closed in April 1, 1897 and the company was declared bankrupt later that month. The Bradford Savings Bank and Trust, which had invested heavily in the mine, collapsed and went into receivership. Fred Farnham, former Ely-Copperfield Mining Company cashier, was kept as superintendent and was appointed an assignee, and pursued sale of the mine. Copper prices rose once again at the very end of the nineteenth century and in 1899 Oliver Garretson, an inventor from Buffalo, NY, started to feed the waste dumps at Ely into an experimental furnace designed to use low-grade ore without roasting. Results were encouraging enough to attract a buyer for the mine (Abbott *GMC* 1964:260-267).

The new owner was inventor George Westinghouse, president of Westinghouse Electric Company. He paid between $85,000 and $100,000 for the property and invested about $1.3 million in new equipment. Westinghouse installed modern equipment including a new ore separator plant, Colorado-style furnaces, Bessemer converters, and new electric mine hoists. During the summer of 1900, engineering students from Dartmouth College surveyed two railroad routes from the mine to the Boston & Maine Railroad on the Connecticut River, but the railroad lines were never constructed. Westinghouse apparently had two motives for developing the property, to experiment with low-grade ore processing, and to hedge a source of copper for his electrical industries in the face of the copper trusts being developed by the Rockefellers in their Amalgamated Copper interests (Abbott *GMC* 1964:266-268).

By February 1901, the mine was pumped out sufficiently so that mining could resume under Capt. Samuel Paul, a Cornish miner who had originally worked for Smith Ely. The ore was smelted in Garretson's furnace and the matte was sent to Pittsburgh for refining. Unfortunately, fortune once again looked unfavorably on the mine. The price of copper fell again, little ore was found at the 3,500 ft bottom of the mine, the ore in the dumps was low-grade, and Westinghouse had difficulties with the town over taxes. The experiments were ultimately a failure. Westinghouse was trying to perfect a practice that had first been tried in 1888 for smelting low-grade ores without roasting and that eliminated intermediate steps that consumed a tremendous quantity of fuel. His goal was to produce a 20 to 25 per cent matte and to refine it to almost pure blister copper in a converter, a tilting vessel that was traditionally used to refine molten pig iron into steel. A key aspect of the process was use of a chemically basic magnesite refractory furnace lining rather than the acid silica firebricks then in use. Westinghouse did make some copper, but the new process was ultimately perfected at a Baltimore smelter in 1909. In 1905, Westinghouse stripped the entire mine property of all equipment and put the mine site and the village up for auction. Ely Ely-Goddard's mansion was sold for $155.00 and moved to the shore of Lake Fairlee (Abbott *GMC* 1964:269). The Methodist Church was moved to the village of Vershire, and the original Catholic Church may have been relocated to West Fairlee.

No ore was ever mined underground from the Ely orebody again, but the site briefly became a source of copper twice. During World War I a flotation mill was set up and 3,600 lbs of copper was taken from the old ore dumps. In 1949 and 1950, 60,000 tons of waste ore bearing 1 percent copper was taken from the dumps and shipped to the flotation mill at the Elizabeth Mine in South Strafford for milling, yielding 1.2 million lbs of copper. Elizabeth Mine owner Appalachian Sulphides, Inc. performed prospecting at the site but opted not to pursue mining (Abbott *GMC* 1964:270).

It is impossible to exactly calculate the Ely Mine's total lifetime copper output or its contribution to Vermont's copper production during the 1870s. Even using the best available figures the total conservative copper output for the mine was between 31 and 34 million pounds, and a figure of 40 million pounds appears to be the most generous estimate. Production in the pre-smelting years, 1854 to 1869, was 3,999,840 lbs. Production in every year from 1868 to 1882 averaged more than 1 million lbs. The Ely smelter made more than 2 million lbs per year in 1879 and 1880 with the ore contribution of the Union Mine at Pike Hill. The production peak was achieved in 1880 when 3,186,175 lbs of copper were smelted. The Ely was among the top ten producing U.S. copper mines between 1866 and 1881. During the 1870s, it was the third largest-producing U.S. copper mine in 1873 and 1875, and ranked fourth through ninth the other years. In comparison, the Calumet & Hecla Mine in Michigan, the biggest U.S. copper producer of that decade, yielded 12 million lbs in 1870 and 31 million lbs in 1880. The significance of the Ely mine lies not just in its role as a considerable contributor to U.S. copper production. It was the largest copper mine working in sulfide ores for a long period of time in which most of the rest of U.S. copper production came from native copper ores. It was the largest single copper producing mine east of the Mississippi River. Its only other close rival was the Union Consolidated Mining Co. at Ducktown, TN, which produced 1 million lbs annually during Ely's period of operation, but often from several smaller mines rather than just one shaft as at Ely. During the second half of the nineteenth century, the Ely Mine easily outstripped the copper production at the Elizabeth Mine at South Strafford (Abbott *GMC* 1964:143-146).

The Ely Mine was the only copper mine in Vermont where all technological aspects of refined pig copper production, from mining of raw ore to smelting of refined copper, were successfully integrated on a large scale. The Ely Mine was significant as a mining boomtown in Vermont. During its approximately 50-year life it became a seat of political power, and spawned and supported the growth of a sizeable rural industrial community.

Since 1950, when the last waste rock was hauled away to the Elizabeth Mine the Ely Mine property has remained largely undisturbed. It is currently used for harvesting timber. Logging activity has resulted in improvement to the mine road between the highway and Dwight Hill, and the mill tailings have been graded to prevent the road through the site from washing out.

5.2 Known and Expected Resources

5.2.1 Current Landscape and Visible Features

The Ely Mine site is located on the road between West Fairlee and South Vershire, about 1.5 miles west of the former village. The most obvious resource is the landscape itself, which is characterized by barren red, orange and yellow earth, slag and dark pieces of lean waste ore. This area is ringed by acid-tolerant tree species including aspen and birch. The mine site is obvious as the highway to the mine opens onto a largely barren area. This area spans the road, and a brook lies to the south. South of the road the south face of the slagheap is exposed where it has been excavated for fill. The hemispherical slag pot skulls are clearly visible in the slag, which consists mostly of iron and silica. A clear area north of the road is the site of the 700 ft long smelter building. Masonry furnace bases with steel supports are located in this area, which was the floor of the smelting shed. Above this area is a high masonry drywall that may have been the back wall of part of the smelter. The stone slab smelter smoke flue extends 1,400 ft northeast up the hill from the rear of the west end of the smelter, and consists of vertical slabs of flat-cleaving local schist with flat capstones.

A dirt road leads north toward the hill, and a fieldstone drywall retaining wall that supported the tramway line from the 900 ft roast beds is located to the east. A clear area to the north includes an ore roast bed area on the east marked by brilliant red soil. The area to the west is cut by a brook and consists of fine sandy material that was spread by the grading of the flotation mill tailings piles. North and uphill from this area are the concrete foundations of the Westinghouse-era mill. From this area north to the base of the hill the ground is barren and strewn with waste rock and ore, as is a considerable part of the hillside where some portions of conical waste rock piles remain. The timber remains of what may be an adit collar or the dressing or washhouse are partially buried under waste rock piles at the bottom of the hill. A road leads west and away from the open area, proceeds up the hill, and turns back east across the face of the hillside to the main shaft entrance. The mine entrance consists of a tall, wide, oval hole in the rock that descends at a steep angle into the mine. Several mine timber roof props are visible inside the opening. The stone foundations of the hoist house with embedded anchor bolts are located opposite the entrance to the mine. Several other shaft openings are scattered around the wooded hillside around the main shaft, obscured by vegetation and exploratory workings. The drainage adit entrance is partially caved in and includes associated building foundations. The original 1834 Tyson adit dump is still distinguishable.

In addition to the historic landscape and individual resources noted in the above discussion, the Ely Mine site contains a number of other visible historic and archaeological resources. These include a dam on the unnamed brook at the bottom of the hill, the quarry east of the mine where the stone was removed for the walls and foundations, and the village cemetery.

5.2.2 Expected Resources

A major class of expected resources at the Ely Mine site are those associated with the village of Ely, which was spread out along the main road, and included a number of civic, company, commercial, and residential buildings. Several miner's houses were located along two parallel roads that extended north from the village and up the hill toward the mine shaft. Expected resources from the village include the foundations of more than 80 buildings, including more than 50 houses, a large general store, one Methodist and two Catholic churches, a school, post office, sawmill, gristmill, blacksmith shop, stables and private businesses. Expected industrial archaeological resources include, but are not limited to, the roasting kilns, smelter coal and coke sheds; the mine office/laboratory; tramway routes, footings and rails; remains of the mills and smelters erected by Cazin, Garretson, Westinghouse, and the smelter brought from South Strafford; the water delivery system including a dam, raceways, wells, culverts and ponds; and prospect pits and tunnels. Because of the scale of operations and activities that can be inferred from the documentary record, it is apparent that many additional industrial archaeological resources can be expected in all areas of the mine site.

5.3 Physical Integrity

Today, the Ely Mine site includes considerable archaeological and some structural remains, but no standing buildings remain onsite from the substantial village that stood around the mine. The mining landscape was altered by the removal of waste rock for copper production during World War I and 1949-1950. This historic activity, which can be classified as continuity of use, and that took place more than 50 years ago, changed the appearance of the Smith Ely-era operation by systematically removing the cluster of large, truncated, conical waste rock piles that originally surrounded the main haulage adit on the side of the hill below the main shaft entrance. The only known major post-mining activity includes removal of some of the extensive slag heap along the brook at the bottom of the hill for fill. Logging activity has included improvement of the original roadway from the highway to the shaft. Some of the mill tailings piles have been graded to control runoff. This activity may have impacted some of the more fragile archaeological resources and contributed to erosion.

5.4 Research Value and Interpretive Potential

There is considerable written historical information about the mining activity at Vershire, but this literature focuses more on the corporate, legal and social aspects of the mine than on its technology. The extensive village zone at the Ely Mine site has the potential for containing a wide range of archaeological resources. Its relative lack of subsequent disturbance contributes to its high research value, particularly for the domestic sites related to the mine community. From an industrial archaeological standpoint, the remains of the roast beds, smelter plant and smoke flue present a unique opportunity to explore one of the largest nineteenth-century non-ferrous metallurgical plants in New England. The sites of the early-twentieth-century flotation plants and smelting experiments, although small, may have the potential to reveal information about the layout and processes at these facilities, which were unusual for New England industry. The extent of literature dealing directly with these experimental operations is unknown. However, even if such literature exists, the archaeological documentation and comparison of the physical remains would be an important contribution to the understanding of this site.

The Ely Mine site has the potential to demonstrate copper production in a linear, understandable way because of several factors. The operations were confined to copper production and for the bulk of the life of the mine copper was produced using similar technology. The early-twentieth-century smelting experiments and World War I and post-World War II activities removed material but appear not to have buried or significantly impacted any major earlier resources. The site geography dictated a confined, straight-line flow of materials in a space that can be readily understood. The major mine features the shaft, roast beds, smelter ruins, smoke flue and slag heaps all retain sufficient integrity to interpret the process of extraction, beneficiation and refining without the overlay of remains of earlier, later and different processes and activity. The site is easy to access as a paved public road passes over the slag heap and smelter site at the bottom of Dwight Hill. However, the property is currently under private ownership and access to the site is subject to landowner permission.

6.0 History, Landscape and Resources of Pike Hill Mines

The Pike Hill Mines site (VT-OR-27), which includes the sites of the Bicknell, Corinth, Eureka, and Union mines, is located in Corinth, 10 miles north of the Ely Mine, on Pike Hill in a remote, hilly, wooded area between the villages of West Corinth and Waits River. The site is located primarily on the top and northeast slope of Pike Hill, although a smaller mine opening, the Bicknell Mine, is located on the south flank of the hill. Corinth's pre-mining history was much the same as Strafford and Vershire. It was a frontier community through the eighteenth century, and relied on a subsistence economy with some local trade in forest products.

Pike Hill was the scene of intermittent mining from 1846 to 1919. The Pike Hill mines went by several names but the largest mining operations were the Union Mine and the Eureka Mine. These operations were close together and resulted in a complex landscape (Figure 6.1). Although they were overshadowed by the Ely Mine and the Elizabeth Mine, they contributed to the Vermont Copper Belt's overall copper production. There was no smelting at Pike Hill; ore mined there was taken to Ely to be refined. One significant technological achievement was magnetic separation of the pyrrhotite from the milled ore. This process, which failed at the Elizabeth Mine, was used successfully at Pike Hill in 1906 and 1907.

6.1 Historic Overview

The Pike Hill ore deposits were discovered after the deposit in South Strafford and Vershire. One story alleges that foxhunters searching for a lost dog found it trapped under a ledge that outcropped in the oxidized earth over the ore. The ore was more likely found in 1845 by Ira Towle on his farm south of Pike Hill on the former farm of Daniel Pike. The Second Annual Vermont state geological report by C.B. Adams noted the discovery of rich copper ore in Corinth. In 1846, Towle and landowner Samuel C. Clement leased the mineral rights to Isaac R. Barbour of Oxford, MA. Barbour and partner Charles Allen dug some ore and sent it to the Revere Copper Works smelter at Point Shirley in Boston, but the mine was not profitable. Barbour opened pits for 3,300 ft along the strike of the ore bed, up the south side of the hill to its summit, where he stopped just short of the major part of the deposit (Abbott *GMC* 1964:5-6, 46, 289).

In 1853, Silas Goddard, also of Worcester, purchased the land north of Barbour's prospects on Pike Hill. Goddard sold the property to two New York men, one of whom, Joseph Bicknell, was one of the original incorporators of the Vermont Copper Mining Company at the Ely Mine. By early 1854, they had formed a company and only worked during the part of the year when the ground was not frozen, and mined the ore in an open cut. By June of the same year the company reported that it had mined 200 tons of ore containing between 16 and 20 percent copper. In November 1855, the company reorganized as the Corinth Copper Company with another incorporator who had interests in the Ely Mine. In 1854, Henry Barnard purchased land north of the Corinth Copper Company, incorporating as the Eureka Mining Company in 1855. Incorporators of the various companies invested in the Ely Mine as well. The mines were not worked seriously until the Civil War, when underground work likely commenced with Cornish miners who had come to Vermont with the Vershire copper boom. In 1863, the Corinth Copper Company had 40 workers and shipped its ore to the east coast smelters. In 1863, the Union Copper Mining Company was formed to work the area north of the Barbour prospects, and included Smith Ely as one of the incorporators (Abbott *GMC* 1964:289-292).

Mining activity on Pike Hill increased during the Civil War, when the price of copper rose to 55 cents a pound. The Corinth Copper Company mine had 52 workers in 1864, and had shipped $18,749.13 worth of ore to the Baltimore and Cuba Smelting and Mining Company in Baltimore, MD. The Union Copper Mining Company opened two short adits on the ore bed and mined 5,000 tons of ore worth $125,000, also sent to the Baltimore smelter. It planned a 665-ft long adit to develop more ore, which assayed between 8 and 10 percent copper. Copper prices dropped after the war ended. By March 1868, the mine closed after the Corinth Copper Company drove a 400-ft adit that missed the vertical shaft by 75 ft. The mine was subsequently abandoned and quickly flooded. In 1869, the Union Mine produced roughly 125 tons of 9 percent copper ore per month. The mine employed 60 men and 11 dwellings were erected to house them. The ore was mined underground via a 300-ft adit and a 200-ft shaft. About 1872, General H.P. Adams worked the Corinth Copper Company deposit with the goal of realizing all the values in the ore, including sulfur, sulfuric acid, and iron as well as copper. He shipped 1,269 tons of copper ore over ten months, but his grandiose plans never came to pass and the mine closed with the Panic of 1873. The Union Mine fared the Panic better and shipped ore averaging 9.5 percent copper to Baltimore in 1874, 1875 and 1876. In 1875, the Corinth Copper Company mine, located 100 yards south of the Union Mine, was reorganized and renamed the Eureka Mine, but was not a success, and closed. The Union Mine finally went bankrupt in 1877 (Abbott *GMC* 1964:292-297).

On November 1, 1878, the bankrupt Union Mine property was purchased by Smith Ely and transferred to the Vermont Copper Mining Company, which owned the Ely Mine at Vershire. Thomas Chase became superintendent, and Captain John Pascoe, brother of Ely Mine foreman Thomas Pascoe, became mine foreman. Additional buildings were constructed, including about 20 dwellings, and a single 180 ft long building with 11 tenements. About 125 men worked at the mine. The mine included a new blacksmith shop, washhouse, and a weigh house with a new set of large ore weighing scales. Smith Ely changed the mine's name to the Goddard Mine, after his grandson, Ely Ely-Goddard. These were the boom years for the Union Mine, when multiple teams of horses were busy hauling ore to the massive smelter at Ely for refining. In May 1879, a new washhouse was built and the ore processing plant was enlarged to accomodate new jigging machines for separating fine ore and waste rock. In October, the washhouse burned, putting almost 150 men out of work. It was quickly rebuilt. Smith Ely began construction of a new road from the mine to the Ely smelter. By February 1880, just as the mine had increased production 400-fold since opening, the ore bed pinched out. The mine all but closed and a few men were retained to try to locate a deeper layer of ore. They failed and the Vermont Copper Company abandoned the Union Mine in 1882 (Abbott *GMC* 1964:96-108, 118, 148, 298).

In 1901, George Westinghouse took an option on the Eureka Mine, but abandoned it after partially pumping it out. In 1902, E.L. Smith also tried to reopen the Eureka, briefly switched to the Union Mine, and in 1907 moved again to the Bicknell Mine on the south slope of Pike Hill, the mine opened briefly by Isaac Barbour in 1846. Smith apparently worked this mine sporadically again in 1913 (Abbott *GMC* 1964:306).

In 1904, New York mining consultant John Allen leased the Eureka Mine from E.L Smith. Allen and Henry H. Knox experimented with a flotation process and magnetic separation, and in 1905 the operation was taken over by Harry G. Hunter, a Philadelphia mining engineer. In 1906, the Union Mine property was sold to Pike Hill Mines, Inc., headed by Allen, Hunter and N.M. Macdonald. This company had success with the magnetic ore separation process and shipped 304,377 lbs of ore in 1906 and 425,367 lbs in 1907. The mill as it appeared at this time is shown in Figure 6.2. Where magnetic ore separation was never successful at the Elizabeth Mine in South Strafford, it succeeded at Pike Hill using similar technology. The plant ceased operating in 1907 when copper prices fell. From 1916 to 1919 flotation experiments were carried on with some success and some copper concentrates were shipped, but operations ceased because of falling copper prices after World War I. The Pike Hill mines were purchased by the new Vermont Copper Company, formed in 1942 to purchase the Elizabeth Mine and were taken over by Appalachian Sulphides, Inc. in 1954. Although the deposits were drilled and assayed by both companies, the Pike Hill mines were never reopened (Abbott *GMC* 1964:306-307).

Although the Pike Hill mines operated sporadically and were only a shadow of the Ely and Elizabeth mines, they did contribute an estimated 8,600,000 lbs of copper to Vermont's overall production, about 1/17th based on analysis of known production figures (Abbott *GMC* 1964:444-448). The Union Mine's other contribution was technological, as it was the only site of successful magnetic ore separation in the Vermont Copper Belt, in 1906 and 1907.

6.2 Known and Expected Resources

6.2.1 Current Landscape and Visible Features

The Pike Hill Mines site is located primarily on the top and northeast slope of Pike Hill, although a smaller mine opening, the Bicknell Mine, is located on the south flank of the hill. The site of the Corinth, Eureka and Union Mines occupies the top and north slope of the hill and is a complex landscape with indistinct and possibly overlapping boundaries between the zones of activity of the three mines. This area is bisected by a dirt logging road. The entire mined area is a combination of barren open areas and patches of acid-tolerant deciduous and coniferous trees. The area northeast of the road includes small piles of mill tailings. The area southwest of and upslope from the road is a complex landscape of trees, small clearings, masonry foundations, large metal artifacts, open mine cuts and trenches, adits, and shafts. An area immediately southwest of the road appears to be the site of the Union Mine ore processing plant as it includes foundations, piles of tailings with protruding lengths of ore tram rails, and the remains of a covered tramway that led to the mine adit.

In addition to the historic mining landscape itself, known visible individual historic resources at the Pike Hill Mines site appear to consist mostly of the remains of the Union Mine. These features include the entrance adit, ore tramway route including trench and retaining walls, ore processing plant site, and associated waste rock and tailings piles. The major transportation feature is the road to the Bicknell Mine and Corinth Center. The site includes various stone foundations that have not been formally identified.

The northeast hillside landscape includes open cuts and minor structural remains south of the Union Mine in the area associated with the Eureka Mine. Other visible historic mining resources on Pike Hill include the entrance and waste rock pile at the Bicknell Mine.

6.2.2 Expected Resources

Expected resources at the Pike Hill Mines site include remains of peripheral mining and domestic infrastructure associated with all four mines. Major expected resources from the Union Mine include the foundations or sites of the blacksmith shop, office/laboratory, wash house, cobbing house, school, 180 ft long tenement building and several other buildings associated with early-twentieth-century milling, flotation and magnetic separation plants. Evidence of additional key structures and features of the Eureka and Corinth mines may also be located along the strike of the orebody.

6.3 Physical Integrity

Today the Pike Hill Mines site includes considerable archaeological and some structural remains, but no standing buildings remain from the small village that grew around the mine. It appears likely that the mining landscape at the northeast foot of the hill was altered by the rearrangement of waste rock associated with extinguishing tailings fires during the 1990s. The only known major post-mining activity consists of logging activity including road building and skidder traffic that may have impacted some of the more fragile archaeological resources and contributed to erosion.

6.4 Research Value and Interpretive Potential

There is far less written historical and technological information about the mining activity on Pike Hill than there is for the Ely or Elizabeth mines. Like the Ely Mine, the

Pike Hill Mines site has the potential for containing a wide range of archaeological resources. Its small size, limited operational time frame, remote location, and relative lack of subsequent disturbance contributes to its research value, particularly in terms of domestic sites related to the mill community. From an industrial archaeological standpoint, the sites of the early-twentieth-century flotation experiments and successful magnetic separation plant have the potential to reveal information about the layout and processes at these facilities, which were unusual for New England industry. The extent of literature dealing directly with these experimental operations is unknown. However, even if such literature exists, the archaeological documentation and comparison of the physical remains would be an important contribution to the understanding of this site.

The Pike Hill Mines, although smaller than the Elizabeth and Ely mines, do include an extensive mining landscape element. The operation of at least three mines at the top and north side of Pike Hill has left a complex site with many mine openings and building foundations that need to be mapped and their functions interpreted. The convoluted, irregular exposure of the orebody across the northeast slope of Pike Hill and the associated open cuts adds to the confusion at the site. The site only included mining and some milling and was worked in a limited way for a limited period of time and may not have the potential for interpreting as full a range of process and technology as either the Ely or Elizabeth sites. Pike Hill can only be reached by four wheel drive vehicle and is remote from paved roads or any significant center of population. The property is currently under private ownership and access to the site is subject to landowner permission.

7.0 Conclusions and Recommendations

7.1 Conclusions

This supplemental report was primarily designed to provide historic context information at the national, regional, state and local levels for the Elizabeth, Ely, and Pike Hill mine sites in Orange County, Vermont. The known and potential historic and archaeological resources at each of the sites were also discussed in terms of their chronological history, including their periods of significance, landscape evolution, and function and technology. Preliminary physical integrity, archaeological research value and interpretive potential evaluations were made. Definitive evaluations and descriptions of the character, condition, and integrity of individual sites, features, standing structures, roads, etc. within the Elizabeth Mine site are not provided as fieldwork was not included in the current scope of work. However, the contextual and descriptive information along with statements regarding overall site significance and interpretive potential will assist the EPA and VT SHPO in determining the effects of proposed cleanup activities on known resources and archaeologically sensitive areas at the Elizabeth Mine site.

7.1.1 The Elizabeth Mine

Of the three Orange County copper mines, the Elizabeth Mine (VT-OR-28) at South Strafford operated over the longest period of time, produced the highest tonnage of copper, and left the largest and most complex mining landscape. It was the location of a major U.S. copperas factory that began in 1809, operated for more than 70 years and eventually dominated domestic production of this important industrial chemical. It was a sporadic producer of various grades of metallic copper and copper ore concentrate from the 1830s to 1930. However, during those years the mine was the scene of several important firsts in American copper metallurgy. After its revival during World War II, it became one of the 20 most productive copper mines in the U.S. and the largest and most productive copper mine in New England.

7.1.1.1 National Register Eligibility of Elizabeth Mine

The significance of the Elizabeth Mine can be expressed through application of the National Register of Historic Places Criteria. The application of the National Register criteria to historic sites and the consideration of the significance of mining landscapes in general is covered in several documents issued by the U.S. Department of the Interior, including *National Register Bulletin 16A: How to Complete the National Register Registration Form*; *National Register Bulletin 42: Guidelines for Identifying, Evaluating, and Registering Historic Mining Properties; National Register Bulletin 36: Guidelines for Evaluating and Registering Historical Archaeological Sites and Districts; National Register Bulletin 30: Guidelines for Evaluating and Documenting Rural Historic Landscapes; and National Register Bulletin 32: Guidelines for Evaluating and Documenting Properties Associated with Significant Persons.*

Additional discussion of the significance of historic industrial properties in general and mining landscapes in particular can be found in *Assessing Site Significance* (Hardesty, Donald L. and Barbara J. Little, Altamira Press, 2000).

The application of the National Register Criteria to the Elizabeth Mine Site was addressed in *Statement of Limits, National Register Eligibility, and Potential Resources in the Proposed APE, Elizabeth Mine, South Strafford, Vermont*, prepared by Hartgen Archaeological Associates, Inc. (October 2000). Based on that evaluation, the EPA determined that the Elizabeth Mine Site is eligible for inclusion in the National Register of Historic Places, based on the documentation provided in the Hartgen report (letter from E. Hathaway to E. Wadhams, dated January 10, 2001). The VT SHPO concurred with the EPA's finding of National Register eligibility and concluded that the site is eligible as the Elizabeth Mine Historic District, although the district's formal boundaries have not yet been determined (letter from E. Wadhams to E. Hathaway, dated march 9, 2001).

The Elizabeth Mine is significant for its contributions to the history of South Strafford, the State of Vermont, and the United States. These areas of significance include commerce, economics, engineering, industry, invention and historic non-aboriginal archaeology. The application of the levels and areas of significance to this site are complex as they do not all apply for all phases of activity that took place during the approximately 160 year period of operation for the mine, which can be considered its period of significance. The Elizabeth Mine was the site of a major U.S. copperas manufacturing plant that dominated production of this important industrial chemical during the mid-nineteenth century. It was the scene of several important firsts in American copper metallurgy, including successful mineside smelting, large-scale smelting of sulfide ores, smelting with hot blast and anthracite, and successful use of chromite refractories. After its revival during World War II it became one of the 20 most productive copper mines in the U.S. and the largest and most productive copper mine in New England.

The Elizabeth Mine is significant for its associations with a number of significant commercial, scientific and political figures. President James Monroe visited the Elizabeth Mine in 1817 as part of a goodwill tour of area industries affected by changing trade regulations. The early nineteenth-century copperas production and copper smelting activities were superintended by Isaac Tyson, Jr., a Baltimore, Maryland-based chemical and mining figure who was recently inducted into the American Institute of Mining, Metallurgical and Petroleum Engineers (AIME) Mining Hall of Fame. During the early twentieth century, extensive mine redevelopment and smelting experiments were undertaken by August Heckscher, general manager of the New Jersey Zinc Company (one of the major U.S. zinc producers) and currently nominated to the AIME Mining Hall of Fame. The mine was the subject of examination and reports by several noted nineteenth- and twentieth-century mining engineers.

The Elizabeth Mine is significant as it embodies the distinctive landscape, engineering and architectural resources that are characteristic of early nineteenth- to mid-twentieth-century American metal mining and processing sites. The Elizabeth Mine constitutes one of the largest and least disturbed historic mining sites in New England. Its landscape includes resources that represent the transition from small-scale nineteenth-century mining to large-scale twentieth-century mining, and both copperas and copper production. It includes a diverse range of features from mining, milling and smelting activity. It includes the only intact cluster of historic hard-rock metal mining buildings in the region. Other significant elements include, but are not limited to, areas devegetated by mining activity, roads and other transportation routes, pits, shafts, tailings and waste rock piles, building foundations and standing remains, and archaeological elements now visible or that may be present based on documentary sources including historic maps and photographs. The surviving World War II flotation mill is a particularly rare resource for the eastern U.S. Deposits of waste material including TP 1, TP 2 and TP 3 are valuable historic resources as they are major landscape features that are expressive of metallurgical technology.

The Elizabeth Mine is significant for its potential to yield information important to history. Many of the components are known or potential archaeological resources. The Elizabeth Mine site has the potential to yield archaeological evidence of industrial and technological activities spanning almost 160 years. The copperas production area has already been identified as an area of particular archaeological sensitivity for its potential to contain information about this poorly understood early industrial process. Other areas have the potential to contain archaeological evidence for various phases of copper ore extraction, transportation, beneficiation and smelting from later phases of activity. Some of these sites are intact and others have been buried under wastes associated with later mining activity. Those very waste materials are also considered archaeological resources at this site. The domestic and processing sites and buildings also have the potential to reveal information about the lifeways of nineteenth- and twentieth-century miners.

7.1.1.2 Historic Values of Areas at the Elizabeth Mine

The surviving historic landscape of the Elizabeth Mine is focused on the core area of 1809-1958 mining activity at South Strafford. Additionally, there are two known discontiguous resources associated with the mine, the Sharon Power Station in Sharon and Pompanoosuc Station in Norwich. The historic resources at the Elizabeth Mine can be viewed in terms of their visual landscape value and their potential archaeological value. Further field investigations may confirm the character, condition, integrity and visibility of the areas and their specific resources and allow more definitive delineation of these areas and assessment of their interpretive value.

Mining involves the physical concentration of capital, manpower, transportation and technology in ways that profoundly influence the landscape. Mining landscapes are the physical result of choices made based on the nature of the geology, location, time period, available technology, market conditions, and other factors that changed and evolved over time. Mining landscapes are complex places with overlapping layers of historic activity and landscape evidence. The historic resources at a mine site are not just limited to standing structures; they encompass the entire landscape and the full range of excavations, waste materials, transportation routes, and other aspects of mining operations. Because of industrial and natural processes, many of the resources at historic mining sites are completely or partially buried and are considered archaeological resources with the potential to reveal important information.

The proposed Environmental Response Alternatives (A.D. Little 2001) have the potential to impact the physical integrity of some areas of the historic landscape and resources at the Elizabeth Mine in different ways and to varying degrees. Some of the alternatives seek to preserve areas of the mine that have been identified as more significant from the standpoints of their historic value. The following section discusses TP 1, TP 2, and TP 3, the three areas of tailings and waste rock that have been identified as the major sources of acid mine drainage and that are slated for the first, Non Time-Critical Removal Action cleanup phase. Evaluation of historically significant resources that may be impacted under the later Remedial phase, including the air vent, and South Open Cut, are not included in this report; they will be addressed during subsequent phases of investigation.

7.1.1.3 Historic Resources in the Non Time-Critical Removal Action Areas: TP 1, TP 2 and TP 3

The most immediate and visible historic resource at the Elizabeth Mine are TP 1, TP 2 and TP 3, the major landscape elements left over from the nineteenth-century copperas production and mid- twentieth-century copper production in the form of waste rock, roast beds, heap leach piles, and flotation mill tailings. These features all possess high historic value as mining landscapes. From a historical perspective, these masses of material are the most obvious and most powerful evidence of the human activity at the mine site and are expressive of important economic and technological changes. These landscape elements possess other values. The size, mass, shape, geometry, texture and color of the tailings, and the lack of vegetation at the mine site are all extremely unusual for New England industrial landscapes. The Elizabeth Mine site has the potential to evoke strong reactions in viewers because of its unfamiliar, even alien, formal elements. The productivity of the mine and range of processes and products resulted in the most extensive and colorful of the Orange County copper mine landscapes. The mining landscape at TP 1 includes the only intact cluster of historic hard rock metal mining buildings in New England, which includes a Flotation Mill that is a unique example of its class in the eastern U.S. These three areas have high potential to interpret copperas and copper ore production technology as well as additional ecological and environmental subjects.

In addition to their visual landscape value, the relative historic values of the tailings piles as archaeological resources must also be evaluated in terms of the potential for impact from proposed cleanup activities. Many of the historic components are known or potential archaeological resources that have the potential to yield archaeological evidence of industrial and technological activities spanning almost 160 years. TP 1 and TP 2 cover the remains of a variety of historic ore beneficiation and smelting sites dating from about 1900 to 1930. Although the bulk of these sites are deeply buried and are not likely to be physically impacted by cleanup activities, the 1900 Tyson mill and blacksmith shop appear to have been located where TP 1 and TP 2 meet east of the World War II mine buildings and their remains could be shallow enough to be potentially impacted by proposed cleanup activities along the west slope of TP 1.

Tailings Pile 3 has been identified as the location of nineteenth-century copperas production and therefore possesses high historic research value for its potential to contain archaeological information that could help interpret this poorly understood early industrial process. Reports generated by the cleanup activity have included the north open cut and all the open land north and east of it in TP 3. The area north of the north open cut, however, was the site of an additional phase of industrial activity not associated with the copperas works, and contains the mine site for the Tyson’s 1882-1890 smelting activities on Sargent Brook at the west foot of Copperas Hill. The area within TP 3 north of the north open cut contains the eastern component of this later activity and is significant as it is a key component of the only historic area at the Elizabeth Mine that clearly shows the entire process of mining, roasting, smelting and slag disposal in an uninterrupted, linear manner. The waste ore lying at the surface in this area, which has been tentatively identified as the main source of metals contamination at TP 3, is likely waste ore left over from the cobbing activities associated with Tyson’s copper ore mining from Shaft No. 1 and Shaft No. 2. This area has the potential to contain archaeological remains of this activity and has research and interpretive value as the source of ore for a series of related features that together demonstrate a complete industrial process.

7.1.2 Ely Mine

The Ely Mine (VT-OR-14) was discovered after the deposit at South Strafford. The Ely Mine was active between the mid-1850s and about 1905, and its main contribution to U.S. copper mining occurred during the 1870s and 1880s. The Ely Mine included a major 1867 smelting plant that expanded to become a massive non-ferrous metallurgical plant, more than 700 ft long with 24 furnaces. During the second half of the nineteenth century, the Ely Mine outstripped copper production at the Elizabeth Mine. The Ely was among the top ten U.S. copper producing mines between 1866 and 1881. It was the third largest-producing U.S. copper mine in 1873 and 1875, and ranked fourth through ninth in the rest of that decade. The mine’s overall production stands somewhere between 30 and 40 million lbs. of copper. The Ely Mine, which was significant as a mining boomtown in Vermont, included a substantial workers’ village and influenced the local economy. It was the scene of labor unrest that resulted in the “Ely War.” It was the site of several early-twentieth-century experiments testing new technologies aimed at efficient extraction of copper from low-grade ores and mine wastes. The Ely Mine was the only copper mine in Vermont where all technological aspects of refined pig copper production, from mining of raw ore to smelting of refined copper, were successfully integrated on a large scale.

The Ely Mine landscape includes roughly 350 acres of land characterized by barren ground, and including slag heaps, waste rock piles, the foundations of a massive smelter, a stone smoke flue, fieldstone retaining walls, roast beds, mine openings and scattered foundations, and the remains of a dam and stone quarry. Expected resources include archaeological remains of an extensive village that included more than 50 houses, a large general store, three churches, a school, post office, sawmill, gristmill, blacksmith shop, stables and private businesses. The scale of operations indicated in the documentary record suggests that many additional industrial archaeological resources can be expected. Post-mining activity includes removal of some of the waste rock for milling at the Elizabeth Mine and removal of a portion of the slag heap. The extensive remains of the unique smelter plant and smoke flue, 900 ft roast beds, and other features present the opportunity to explore one of the largest nineteenth-century non-ferrous metallurgical plants in New England, archaeological documentation of which would be an important contribution to the understanding of this site. The Ely Mine site has the potential to interpret copper production in a clear way as operations were temporally confined using similar technology, and the geography dictated a confined, straight-line flow of materials that can be readily understood. The site is easy to access by public road, but, the property is currently privately owned.

7.1.3 Pike Hill Mines

The orebody at the Pike Hill Mines (VT-OR-27) in Corinth was discovered after the deposits in South Strafford and Vershire. Pike Hill was the scene of intermittent copper mining from 1846 to 1919. The Pike Hill mines went by several names but the largest were the Union and Eureka mines. Although the Pike Hill mines operated sporadically and were overshadowed by the Ely Mine and the Elizabeth Mine, they contributed an estimated 1/17th of the copper produced in the Orange County Copper Belt. There was no smelting at Pike Hill; ore mined there was taken to Ely to be refined. One significant technological achievement was magnetic separation of the pyrrhotite from the milled ore at the Union Mine. This process, which failed at the Elizabeth Mine, was used successfully at Pike Hill in 1906 and 1907. The mine workings of the Pike Hill mines were close together and left a complex landscape with indistinct and overlapping boundaries between the areas of activity. This landscape includes barren areas, mine openings, materials handling features, small piles of mill tailings, masonry foundations, and large metal artifacts.

Today the Pike Hill Mines site includes considerable archaeological and some structural remains, but no standing buildings remain from the small village that grew around the mine, or the blacksmith shop, office/laboratory, wash house, cobbing house, school, tenement house and several other buildings associated with early-twentieth-century milling, flotation and magnetic separation plants. The area is bisected by a logging road and waste rock has been moved to extinguish fires. There is less written historical and technological information about the mining activity on Pike Hill than there is for the Ely or Elizabeth mines. The sites of the early-twentieth-century flotation experiments and successful magnetic separation plant have the potential to reveal information about the layout and processes at these facilities. The site only included mining and some milling and was worked in a limited way for a limited period of time and does not appear to have the potential for interpreting as full a range of process and technology as either the Ely or Elizabeth sites. The Pike Hill site is physically remote and privately owned.

7.1.4 Summary of Historical Significance of Orange County Copper Mines

The three mine sites in the Orange County Copper Belt discussed in this supplemental report operated at various times between 1809 and 1958, and made Vermont the largest copper-producing state in the U.S. for part of the 1870s. These mines contributed copper for conflicts from the Civil War to the Korean War, and were the scene of technological advances and labor strife. They all left legacies in the form of unusual historic landscapes and associated features, some that are common to all three mines, and some that are unique to one mine, or to mines in Vermont, New England, the Appalachians, or even the United States. Each site is different and possesses its own unique history, resources and values. Comparisons between the three mine sites are useful for assessing their relative integrity and archaeological and interpretive value.

The Elizabeth Mine site constitutes the largest historic mining landscape of the three Orange County copper mine sites. Unique to the Elizabeth Mine are the copperas production area, the World War II-era landscape including TP 1, TP 2, and the intact cluster of mine plant buildings including the rare flotation mill. The site is also unique for its multiple smelting sites, including the early 1830s site and 1880s Sargent Brook site.

The Ely Mine site is important as an extensive and relatively undisturbed nineteenth-century mining and smelting complex and community site. Its unique resources include the remains of the massive smelter plant and stone slab smoke flue. It is significant for the way the linear progression of the mining, roasting and smelting process is expressed in the surviving landscape.

The Pike Hill mines were important for their contribution to the Ely Mine’s production. It is unique in the Vermont Copper Belt as the site of successful magnetic separation efforts.

7.2 Recommendations

From a historic preservation standpoint, the best cleanup alternatives for resources of archaeological value are those that avoid impacts altogether by isolating critical archaeologically sensitive areas, or that combine site avoidance with an archaeological data recovery component for those areas that cannot be avoided. The proposed cleanup options have the potential to impact the historic landscape values of TP 1 and TP 2. The best cleanup alternatives for resources of visual landscape value are those that retain and/or recreate the basic formal elements of the historic resource, including size, mass, shape, geometry, color, and texture. Retention of these areas and qualities also offers an advantageous result in terms of future uses for the mine, if those are to include an environmental and/or historic interpretive component. The presence of a rare site like the Elizabeth Mine where the hand of man upon the landscape is so starkly obvious also has great potential value for environmental education.

The background research conducted for the supplemental report has determined that there is a strong likelihood that archaeological deposits related to late nineteenth and early twentieth-century industrial activities at Elizabeth Mine exist under TP 1 and TP 2. The majority of these resources are most likely deeply buried up to 110 ft below surface. Capping the tailings would make access to buried archaeological sites for further research more difficult, but would not affect their physical integrity. Grading the tailings would not physically impact these remains. The southwest tip of TP 1 and the north tip of TP 2 are particularly sensitive archaeological resource areas that could contain remains of the ca. 1900 Tyson mill and blacksmith shop. These resources may be located closer to the surface, and these areas may require the installation of drains as part of the cleanup alternatives. Should ground disturbances be planned in these areas as part of clean-up activities, further historic and archaeological research might be warranted in consultation with VT SHPO. This research would include additional documentary records studies along with field survey and excavations to locate, identify, and evaluate significant archaeological resources that may be affected by the proposed cleanup activities.

Additional documentary research is needed to assess the potential for the presence of pre-mining period resources, to determine the presence of additional expected mining resources, and to more precisely locate known resources in areas that are slated for cleanup activities. Field survey and excavations may also be warranted in areas slated for associated cleanup activity such as construction sites, staging locations, batching plants, borrow pits, and associated transportation routes, truck turnarounds, etc.

A fieldwork component needs to be included in any subsequent studies of the Elizabeth Mine site undertaken as part of the planned cleanup work. Fieldwork is critical to assess the visibility, character, condition, and integrity of known resources and to locate expected resources. The initial field survey should include GPS mapping of the entire site to generate an overall Elizabeth Mine Historic Resources Base Map that precisely locates and delineates all areas and resources in relation to known natural and man-made features. This activity should also include detailed mapping of the World War II-era mine plant buildings and associated features. Careful mapping of all historic features on TP 3 should be integrated into any geochemical surveys and mapping of that area to correlate contamination sources and other data with the locations of features to better understand how the copperas works functioned, and to serve as a basis for decisions about cleanup activities. Documentation of the existing conditions at the Elizabeth Mine may require innovative approaches such as color photography, video, or other methods to capture the color, scale and other important formal elements of the landscape, in addition to the conventional documentation methodology including black-and-white photography, mapping and narrative history. The social history of the mine, which was not addressed in this report, is another area that requires further research and documentation.

Any future archaeological studies at Elizabeth Mine should also include close coordination and communication between the cultural resources team and project design and engineering staff at the Environmental Protection Agency, Army Corps of Engineers, Vermont Agency of Natural Resources Department of Environmental Conservation, and Arthur D. Little Inc. as cleanup plans advance toward the design phase.

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